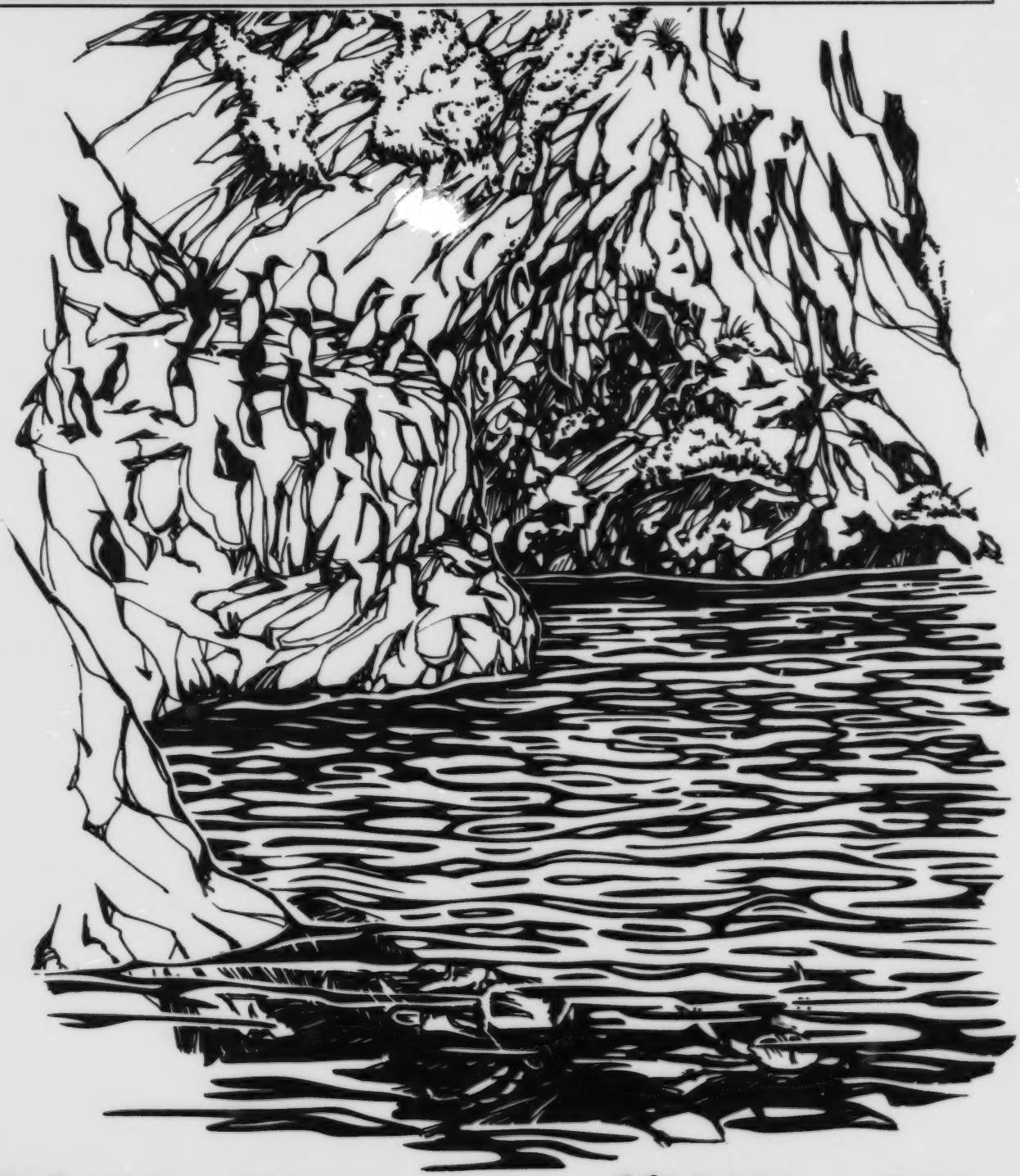
THE NESTUCCA OIL SPILL

Preliminary Evaluation of Impacts on the West Coast of Vancouver Island



Environment Canada
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THE NESTUCCA OIL SPILL: PRELIMINARY EVALUATION OF IMPACTS ON THE WEST COAST OF VANCOUVER ISLAND

Prepared for

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West Vancouver, B.C.

and

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NESTUCCA ENVIRONMENTAL IMPACT ASSESSMENT

BACKGROUND

Following oil contamination on the west coast of Vancouver Island from the stricken barge, Nestucca, the B.C. provincial and federal Ministers of Environment, the Hon. Bruce Strachan and the Hon. Lucien Bouchard, asked for a full assessment of the impact of the spill. The Minister of Fisheries and Oceans (DFO), the Hon. Tom Siddon, also expressed support for a thorough environmental assessment. This report has been prepared in partial fulfilment of the Ministers' request for an impact assessment.

PRELIMINARY ENVIRONMENTAL IMPACT ASSESSMENT

The B.C. Ministry of Environment and the federal Department of Environment jointly initiated and funded this Preliminary Evaluation of the Environmental Impacts of the Nestucca oil spill. The purpose of this report is to document the early (to March 31) distribution and movement of oil along the west coast of Vancouver Island in relation to known environmental resources to guide subsequent studies of the possible longer-term impact. The report also summarizes documented environmental impacts during this early period.

DISCLAIMER

Tentative conclusions drawn in this report are based on preliminary analysis of data and may change with additional analysis and new information. This report is without prejudice to any legal action.

ACKNOWLEDGEMENTS

This report was prepared by ESL Environmental Sciences Limited, a member of the Seakem Group, under contract to Environment Canada (EC) and the B.C. Ministry of Environment (MOE). Preparation of the report was supervised by the Environmental Impact Assessment Team under the direction of Colin Wykes (EC), John Davis (DFO) and Bob Langford (BCMOE). Carey McAllister, Colin Levings, Jill Morrison and Jim Boutiller of the Department of Fisheries and Oceans assisted in monitoring and impact assessment and were major contributors to the evaluation. The contract for this report was jointly managed by Lee Harding (EC) and Bob Langford (MOE). Mike Flynn coordinated DFO input. Maps were digitized by ESL under the direction of Peter Wainwright, from marine charts published by the Canadian Hydrographic Service.

Many people contributed to this assessment, including DFO scientists, fisheries officers, technical and operational support staff and people with essential local knowledge of the environment and conditions on the west coast. The Environmental Impact Assessment Team especially wishes to acknowledge the contributions of Moira Lemon of CWS and Michael Rodway, seabird specialist; Larry Baird, Chief of the Ucluelet Indian Band; Bill Green, Fisheries Policy Advisor for the Nuu-Chah-Nulth Tribal Council; Norman Dale, environmental coordinator for the Kwakiutl Territorial Fisheries Commission; and Karl Sturmanis, band planner for the Kwakiutl District Council.

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EXECUTIVE SUMMARY

On 23 December 1988, a collision occurred between the fuel barge Nestucca and its tender tug Ocean Service off the mouth of Grays Harbour in the state of Washington. The barge had a cargo capacity of 11.2 million litres and was transporting heavy Bunker C oil. An estimated 875 000 L of this volume was reported to be spilled near Grays Harbour, which is located 175 km from the US-Canada border. An unknown proportion of this oil moved north and eventually stranded on shorelines along the west coast of Vancouver Island in British Columbia.

A federal-provincial team was assembled on 5 January to assess the short- and long-term environmental impacts of the spill. The composition of this team, which evolved during the scientific response, included representatives of DOE (Environmental Protection, Canadian Wildlife Service, Parks Canada), Fisheries and Oceans Canada (DFO), Energy, Mines and Resources (Geological Survey of Canada), B.C. Ministry of Agriculture and Fisheries (MAF), B.C. Ministry of Environment (Planning and Assessment; MOE), and the Nuu-Chah-Nulth Tribal Council. Integration of the Canadian response to the Nestucca spill was achieved by locating staff from the government agencies within the Amphitrite Point Operations Centre and participation of representatives of different agencies, and members of the Nuu-Chah-Nulth Tribal Council and Kwakiutl District Council in daily Regional Environmental Emergency Team (REET) meetings.

Several projects and activities were initiated to determine the immediate or short-term impacts of the Nestucca oil spill on the biophysical environment of the west coast of Vancouver Island. The results of many of these studies are described in this report, while other investigations are only identified here and will be discussed in more detailed reports to be prepared by various federal and provincial government agencies. Longer-term research programmes are in progress or are being planned on the fate of oil in key environmental compartments and the effects of Bunker C from the Nestucca on Valued Ecosystem Components. The overall objective of such investigations would be to assess the impact of the Nestucca oil spill on the Canadian marine environment.

Bunker C oil from the Nestucca moved north past Cape Flattery, Washington and stranded at Carmanah Point in British Columbia on 31 December 1988. Subsequent movements of oil along the west coast of Vancouver Island were longshore, and driven by a combination of winds and prevailing currents. Within 17 days of its initial stranding on the southeast tip of Vancouver Island, oil was detected in the Triangle Island Group and along the shores of Cape Scott on the northern tip of Vancouver Island. Some oil also moved southwest, stranding near Sooke at the southern tip of Vancouver Island. In general, oiling was confined to exposed outer shorelines (rocky headlands, beaches and cobble areas). Little oil was transported into coastal inlets and fjords. However, small quantities of oil reached the seafloor in a few nearshore areas. Preliminary estimates suggest that about 150 km of beaches and intertidal areas were contaminated to some extent with oil from the Nestucca, although segments of shoreline totalling 2-3 km were considered

"heavily oiled". It is possible that some of the re-oiling of beaches along the Tofino-Ucluelet coastline following storms was due to the presence of submerged rather than surface oil off these sandy beaches.

Oil from the Nestucca was observed in a variety of different forms in marine environments along the coast of Vancouver Island. Types of oil varied from thin sheens to heavy encrustations on rocks and logs, "patties" of varying size and density, oil fouled in eelgrass and algal growth, and heavy black sticky oil adhering to crab traps and on the carapaces of Dungeness crabs. Bunker C from the Nestucca was at sea from 1-3 weeks before stranding in coastal areas of Vancouver Island and underwent substantial "weathering" during this period, despite the low air and water temperatures in January. Nevertheless, strong odours and visible sheens persisting through March indicated that some volatile fractions remained during this period.

The Nestucca spill resulted in some mortality and damage to plants within the intertidal zone. Much of the oil-contaminated debris removed by clean-up crews during shoreline restoration programs was storm-blown kelp and eelgrass. Losses of intertidal algae occurred in rocky and sandy habitats, particularly in those areas where either the entire intertidal zone was coated with oil or oil stranded in upper intertidal areas over successive tidal cycles (i.e., where re-oiling occurred).

Salt-marsh habitat in a lagoon at Friendly Cove on Nootka Island was extensively contaminated with Bunker C and required an intensive clean-up effort. Marsh grasses can be severely affected by oil contamination and can require many years to recover. This is because of the tendency of oil to penetrate and persist in the sediments, thereby resulting in long-term toxic effects as a result of the uptake of petroleum hydrocarbons through the root systems of these plants. Salt-marsh habitats are very sensitive to oil spills. Despite efforts to remove most of the oil-contaminated marsh vegetation from Friendly Cove, it is probable that at least some oil penetrated the sediments and that additional oil remains on un-cropped grasses.

There were no observations of the effects of the Nestucca spill on benthic infauna (invertebrates living within the upper layer of sediments on the seafloor). Mortality of infauna has only been documented infrequently following bunker fuel spills.

There were several reports of large numbers of dead crabs, although many were shed exoskeletons (normal during moult), and one observation of dead sea urchins. It is not known if these were spill-related. Crustaceans (e.g., crabs) and echinoderms (e.g., sea urchins) are the predominant taxonomic groups comprising the epifauna (invertebrates found on or in association with the seafloor), with the former suffering greatest losses following past oil spills. Mortality appears to be highly dependent on the circumstances surrounding spills, and was not observed during subtidal dive surveys conducted by assessment specialists. However, the fact that oiled Dungeness crabs were recovered from traps in a few areas indicates that exposure occurred in at least some habitats. Oiled crabs were still being reported at the end of March 1989. DFO collected samples of Dungeness crabs and other invertebrates from areas with possible oil contamination. These

samples were tested for the presence of hydrocarbons by chemical and organoleptic (taste/odour) analyses.

Observations of dead gammarid amphipods on oil mats indicate that some losses of intertidal fauna occurred in areas where oil stranded. Intertidal invertebrates have often been one of the most visibly affected biological resources following oil spills. The dominant taxonomic groups in rocky areas are gastropods (e.g., limpets, snails), sessile crustaceans (e.g., barnacles) and some bivalve molluscs (e.g., mussels), while bivalves (e.g., clams, oysters), worms and mobile crustaceans (e.g., amphipods) tend to predominate in sandy habitats. The most common cause of mortality among intertidal species is smothering by thick layers of stranded oil. There is often complete elimination of intertidal fauna in heavily-oiled areas. This may have occurred in the relatively localized areas that were heavily oiled.

One of the concerns of DFO related to this spill was the potential impacts of Bunker C in intertidal and shallow subtidal habitats, particularly in important, historic herring spawning areas such as the shoreline of Barkley Sound. Herring adults, eggs, larvae and juveniles occupy certain nearshore habitats at specific times of the year, and at times, are highly susceptible to oil pollution. Oil stranded near herring spawn areas along the western shore of Barkley Sound between Toquart Bay and Ucluelet, and a spawning area in Ucluelet Harbour was heavily oiled. However, herring and herring spawn passed all organoleptic inspections.

There are numerous salmon spawning streams, estuarine habitats and nearshore salmon rearing areas along the West Coast of Vancouver Island. Generally these areas are located along sheltered portions of the coast and were not areas directly affected by oil from the Nestucca.

The impact of this oil spill on other fish species such as Pacific cod, rockfish and lingcod is largely unknown. Bottom-dwelling fish may be affected if their habitat or prey were contaminated by oil.

The most apparent initial impact of the Nestucca oil spill was the death of approximately 12 500 seabirds in British Columbia and Washington. About 9000 dead birds were counted in Washington and a total of 3568 dead birds was found on shores of the west coast of Vancouver Island between 3 January and 1 April 1989. Dead birds were found over the entire length of Vancouver Island from Sooke to Cape Scott, although most birds were recovered from beaches within Pacific Rim National Park and the Tofino/Clayoquot Sound area. This is at least in part because of the intensity of the cleanup efforts in these areas. The Canadian Wildlife Service suggests that because these areas were frequently and thoroughly inspected, counts are probably close to the actual numbers of birds that washed ashore in these particular areas. Data available for other areas likely underestimate actual mortality. In addition, birds were not separated from oil debris during the cleanup in some areas, while other dead birds would have sunken at sea before reaching the coast of Vancouver Island. As is the case in many oil spills, alcids (Common Murres and Cassin's Auklets) were most seriously affected by oil contamination. The overall impact of this spill on Canadian populations of these and other bird species will not be known until summer breeding colony

surveys have been completed.

During the response to the Nestucca spill, top priority was given to assessment of the presence or absence of oil in the vicinity of two sea otter colonies. Sea otters are an endangered species and, at present, there are only two known colonies in Canada (Kyuquot Sound and Bajo Reef). In addition, sea otters are known to be both highly vulnerable and sensitive to oil exposure. The otter colonies were monitored on a regular basis by DFO. Although significant amounts of oil were observed in the immediate vicinity of an otter colony, only one oiled dead animal was collected on Gull Islet (Bunsby Island area). The carcass was later autopsied and the cause of death was confirmed to be related to oil. Otherwise, the behaviour and distribution of sea otters appeared normal. Observations of otters were conducted under winter conditions often in bad weather with limited visibility, and are not comparable with summer surveys.

Although some oil-contaminated seals and sea lions were reported, impacts of the Nestucca spill on either group appears minimal. In all cases, the animals appeared healthy and exhibited normal behaviour. Eight seals, 18 sea lions and 2 elephant seals were reported to have come in contact with oil in the coastal waters of Vancouver Island, although deaths related to oil could not be confirmed for these species.

Commercial fishing provides the primary source of cash income for many west coast communities. However, preliminary assessment data indicate that the Nestucca oil spill had no significant impact on salmon or groundfish fishery resources. Although fishing generates the highest income, clam digging is also an important source of income for commercial fisheries, particularly during the winter months. Shellfish is also an important staple in the diet of Native families. DFO Statistical Areas 23 and 24 were closed for some commercial shellfish harvesting on 6 January to 18 and 25 January, respectively, as a precautionary measure. Area 23 was closed for all bivalves and Area 24 for gooseneck barnacles and mussels.

Fish farms on the west coast of Vancouver Island are located in protected areas away from the exposed headlands and islands that received most of the oil following the Nestucca spill. At the time of the data collection for this report, the oil had little apparent effect on the salmon farming industry in this region. Shellfish leases and wild stocks of shellfish are generally located in sheltered bays and along protected areas of the shoreline; conversely, most of the oil from the Nestucca affected exposed outer coast areas. At this time, no cultured oyster stocks have been reported to be contaminated as a result of the spill. The only impact reported by the shellfish farmers was a temporary loss of harvest opportunities during the short-term precautionary closures of Statistical Areas 23 and 24 for shellfish harvest. Commercial clam diggers in the Barkley Sound area had to forgo potential clam harvests from 21 tides during January due to the shellfish closure.

There was widespread, low-level contamination of recreational beaches throughout the region. Personal enjoyment of visitors and residents may be reduced due to presence of oil on the beaches, particularly if they perceive that environmental quality, wildlife and park beach resources have deteriorated as a result of the event. The Pacific Rim National Park extends from Port Renfrew to Point Cox and includes the Broken Group Islands. The park environment supports numerous tourist-related activities that may be adversely affected if evidence of oil contamination persists within the area. The park is internationally recognized as an accessible, protected, and natural coastal environment. Half a million tourists visit the park annually to view and experience a variety of unique and ecologically sensitive environments. The short-term impacts of the Nestucca spill on tourism to this area were difficult to quantify at the time of the spill because very few people visit the park during the winter months. Long-term impacts of the spill on the rate of visitation to the park may become evident later in the year and in subsequent years.

1.0 INTRODUCTION

Sometime between midnight and 3 a.m. on 23 December 1988, a collision occurred between the fuel barge Nestucca and its tender tug (Ocean Service) about 3 km off the mouth of Grays Harbour in the state of Washington. The cause of the accident is still under investigation by U.S. authorities, although the news media reported that the collision resulted when the tug rammed the barge while the crew were attempting to retrieve the tow line in moderately rough seas.

The Nestucca had a cargo capacity of 70 000 barrels (11.2 million litres) and was transporting heavy Bunker C (No. 6 fuel) oil. An estimated 875 000 L of this volume was reported to be spilled off Grays Harbour, which is located 175 km from the US-Canada border.

According to USCG reports, the damaged barge was towed in rough weather southwest to a location 45 km off the mouth of the Columbia River. The following day, a temporary patch was placed on the Nestucca and it was then towed to Astoria, Oregon for repairs.

2.0 OVERVIEW OF RESPONSE ACTIVITIES

2.1 Oil Tracking and Reconnaissance Activities

Oil tracking and reconnaissance activities involved the use of a variety of vessels, fixed-wing aircraft and helicopters. When weather permitted, regular overflights of Juan de Fuca Strait, the west coast of Vancouver Island and the northern tip of Vancouver Island were conducted by DFO's Institute of Ocean Sciences (IOS). Oceanographers Al Ages and Rick Thomson provided morning and evening spill trajectory projections based on knowledge of coastal circulation dynamics and local weather information that was obtained through the Environment Canada (AES) Marine Desk at their Vancouver Headquarters. These projections were summarized daily by DFO staff at the meetings held at the Amphitrite Point Operations Centre. DOE staff

examined environmentally-sensitive areas, such as seabird colonies and native resource harvest areas, in the projected oil path and reported oil locations to the Operations Centre. They were then used to help set daily priorities, deploy clean-up and response crews and establish helicopter and vessel surveillance locations to respond to projected northern movement of oil. When re-oiling of previously cleaned areas began on 12 January, DOE and the two tribal councils began daily surveillance of beaches to detect re-oiling. Helicopter support was used to deploy local people, who then walked selected sections of shoreline.

Other oil spill reconnaissance flights were conducted on a frequent basis by the CCG, DOE and groups of assessment specialists from several federal and provincial government agencies.

Much of the information on the location of surface oil slicks and stranded oil in shoreline areas was collected by personnel engaged in surveillance and impact assessment activities. Vessels deployed by DFO for various surveys included the J.P. Tully, Atlin Post, Comox Post, Arrow Post, Sea Crest, Solar Wind and Brama.

2.2 Oil Spill Clean-up Activities

The CCG maintained a record of the activities of all personnel involved in the clean-up response. This information was summarized and released each evening in the form of situation reports ("Sitreps") up to 12 January and "Oil Spill Facts" reports beginning on 13 January. These reports included the following types of information.

- Daily estimates and cumulative totals of the quantity of oil and debris recovered by clean-up personnel;
- The numbers of personnel (by organization and site) involved in clean-up operations;
- Equipment in use by the CCG and spill clean-up contractor;
- The weather forecast for the next 24 hours;

- Information on the locations of oil sightings, and impacts of the event; and
- Activities of both government and non-government personnel involved in the response.

2.3 Clean-up Approach and Techniques

2.3.1 Containment and Recovery

There were no attempts made to contain or recover oil at sea during the Canadian response to the Nestucca oil spill. By the time oil reached the B.C. coast it was so widely dispersed that containment was not a feasible option. In addition, poor weather often accompanied by gale to storm force winds was common. In the exposed outer coast, containment through the deployment of booms also would have not been effective. Because the surface oil slicks could not be contained, the use of skimmers and other oil recovery techniques was not considered.

2.3.2 Shoreline Protection

There were three situations where protection of threatened habitat and wildlife populations was considered during the response to the Nestucca spill. The first environmental protection decision related to the re-oiling phenomenon described later in Section 4.4. When re-oiling of beaches was predicted on 11 January and then observed on 12 January, response personnel considered leaving oil on the shorelines until the re-oiling events had ended, largely to minimize the costs of repeated clean-up. However, the decision was made to clean shorelines as often as they were oiled and to remove as much oil volume as possible. Part of the rationale for this decision was to minimize the lifting of oil by high tides and storms, with its subsequent potential redistribution to uncontaminated beaches. On-scene assessment personnel believed this to be an effective strategy that minimized environmental damage in several areas.

The second instance occurred when spill trajectory predictions by DFO and observations by aerial surveillance teams suggested that oil slicks were moving in the direction of the Bunsby Islands. This area is an Ecological Reserve and is considered important habitat for both marine mammals and birds. Protective measures considered by response personnel included application of chemical dispersants and the deployment of booms to prevent oil from reaching sensitive habitats in the Bunsby Islands area. However, the application of dispersants would have been completely ineffective with this heavy oil. Similarly, it was indicated that use of containment booms would be virtually impossible given the rough seas at the time. As a result, none of the above protective measures were employed. Intensive surveillance and prompt cleanup crew response when oil was sighted on shorelines was substituted in lieu of the above protective measures.

A third instance where environmental protection was considered resulted after oil was observed in the Cape Scott area. Placement of booms across the mouth of Hansen's Lagoon was evaluated to protect wintering waterfowl. It was concluded that booms would not have been effective because heavy swells, driven by southwest gale-force winds, were breaking in the narrow mouth of the inlet.

2.3.3 Shoreline Restoration

Beach Cleanup

Most of the oil cleaned from beaches was removed by conventional manual techniques. Oil and oiled debris (e.g., eelgrass and small pieces of driftwood) on sand or gravel beaches were shovelled or raked into plastic bags, which were collected and taken to temporary storage. Where possible, oil was scraped off larger boulders and some beach logs and transferred to plastic bags for storage. Construction equipment (e.g., a backhoe) was used to collect and remove oil from accessible beaches near Tofino. After collection, oil and oil-contaminated debris was stored in a temporary facility near Tofino and eventually shipped out for burning in municipal incinerators.

Petromesh

Petromesh, a commercial, oil-absorbing fabric, was used occasionally to scrape and absorb oil from boulders and cobbles. In a heavily-contaminated eelgrass bed in Stuart Bay near Ucluelet, petromesh was anchored with rocks and oil-absorbing pom-poms were buried in sand and later recovered. This procedure was repeated until sorbents began appearing clean after a tidal cycle.

Test Burning of Oiled Rocks with a Gasoline Gel Product

A gasoline gel product was used to initiate combustion of oil contaminating rocks under experimental conditions at the CCG Base at Amphitrite Point. The residue was then submitted to the Environmental Protection Lab (DOE) in West Vancouver for analysis by gas chromatography, and the results forwarded to on-site staff. A decision was made to not use this product based on the results of this analysis, which showed very little degradation of Bunker C.

Test Burning of Oiled Rocks with Tiger Torches

Tiger torches (portable, propane-fired burners) were used on a trial basis at Amphitrite Point and later *in situ* at Bajo Point (a heavily-oiled, cobble beach that was considered environmentally sensitive). Otherwise, the technique was not used operationally because of its general ineffectiveness and the fact that it mobilized the oil, thereby increasing the risk of oil penetration into gravel substrates and formation of new oil slicks on the water surface.

Test Burning of Oiled Rocks with a Reciprocating Kiln

At Bajo Point, a heavily-oiled cobble beach near a sea otter colony and adjacent to an archaeological site and existing Indian Reserve, a reciprocating kiln was used to burn oiled cobbles and gravel. It was

constructed in Ucluelet from plans provided by CCG, based on one built during the response to the Arrow spill in Nova Scotia during 1970, and transported to the site by helicopter. However, the burning was found to be inefficient, possibly because of the small amount of oil still present on the cobble and gravel by that time (February) or the small design throughput volume of the kiln. Some of the more contaminated beach substrate had been removed earlier and transported to an abandoned log deck inland from the beach.

Burning of Oiled Logs

Heavily-oiled logs were burned at several locations including: several islands within the Broken Islands Group and elsewhere within Barkley Sound; important tourist beaches in the Long Beach area; Estevan Point; and the Brooks Peninsula.

Cropping of Oiled Eelgrass

Eelgrass, an extremely important primary producer in some west coast ecosystems, was fouled by the viscous, sticky bunker fuel from the Nestucca. Extensive eelgrass beds in the Stubbs Island area are the primary food supply for migrating Brant and are a major contributor to detritus-based food webs supporting Dungeness crabs, grey whales and other important marine resources. Substantial amounts of adhering oil were observed in these eelgrass beds at the start of Brant migration (early February) and, therefore, clean-up crews cropped and removed the exposed, contaminated vegetation at a low (1 m) tide.

3.0 ASSESSMENT PROCEDURES

DFO field staff based in Port Alberni and Tofino began collecting shellfish samples for organoleptic (taste/odour) analysis in DFO Inspection Laboratories and advising DOE emergency response personnel of concerns on 4 January 1989. On this day, Environment Canada staff also began reconnaissance of Pacific Rim National Park shorelines, and Vancouver-based response experts

began oil surveillance by air and initiated an oil sampling program. DOE shellfish specialists also provided an analysis of threatened shellfish resources on that date.

A federal-provincial team was assembled on 5 January to participate in establishing clean-up priorities and to assess the short- and long-term environmental impacts of the spill. The composition of this team evolved during the scientific response to the spill, and included representatives of DOE (Environmental Protection, Canadian Wildlife Service, Parks Canada), Fisheries and Oceans Canada (DFO), Energy, Mines and Resources (Geological Survey of Canada), B.C. Ministry of Agriculture and Fisheries (MAF), B.C. Ministry of Environment (Planning and Assessment; MOE), and the Nuu-Chah-Nulth Tribal Council. The environmental assessment team was supported by a contracted consultant, ESL Environmental Sciences Limited. The coordinators of the environmental assessment team from DOE (L.E. Harding) and MOE (R.W. Langford) arrived in Ucluelet on 7 January to begin assembling information and establish procedures for collection and interpretation of environmental data. On 9 January, the Hon. Lucien Bouchard, Minister of Environment, and the Hon. Tom Siddon, Minister of Fisheries and Oceans, and the provincial Minister of Environment, the Hon. Bruce Strachan, visited the site, met with native and community leaders and held a news conference. DFO expanded their assessment program at the Oil Spill Command Centre in Ucluelet on 10 January. On-site staff under the leadership of Dr. John Davis, Director of Science for Pacific fisheries included marine mammal specialists, dive teams for subtidal surveys, shellfish biologists, and habitat protection, benthic ecology and environmental assessment specialists.

On 11 January, the Federal Minister of Environment (Lucien Bouchard), in agreement with the B.C. Minister of Environment (Bruce Strachan) and the Minister of Fisheries and Oceans (Tom Siddon) announced an expanded environmental assessment program. The program had two parts: (1) a daily analysis of natural resources and environmental sensitivities to establish clean-up priorities; and (2) overall assessment and impact of the Nestucca spill in Canada. Mr. Colin Wykes, Director of Environmental Services for

Environmental Canada's Pacific Region was appointed to lead this assessment with the support of DFO and B.C. MOE. The B.C. Ministry of Agriculture and Fisheries also provided information on impacts to shellfish and finfish aquaculture operations.

Other agencies were involved in non-assessment related aspects of the response such the Atmospheric Environment Service (DOE), who provided weather forecasts, and the Waste Management Branch (MOE), who provided advice on possible disposal sites for oil and oil-contaminated debris collected during shoreline clean-up activities.

Integration of the Canadian response to the Nestucca spill was achieved by locating staff from the government agencies within the Amphitrite Point Operations Centre and participation of representatives of different agencies, and members of the Nuu-Chah-Nulth Tribal Council in daily Regional Environmental Emergency Team (REET) meetings. Representatives of the Kwakiutl District Council also attended some REET meetings to discuss northern issues. REET meetings were scheduled each evening to discuss and map new oil sightings or re-oiled areas, establish priorities for protection of resources considered at risk, and identify areas that should be the focus of clean-up efforts on the following day.

On most days, four briefings were prepared and exchanged among representatives of government agencies involved in the clean-up response or assessment activities. These were:

- **CCG SITUATION REPORTS OR OIL SPILL FACTS SHEETS**, which summarized the events of the day including new oil sightings, activities of various agencies and groups involved in the response, areas where clean-up operations were focused, impacts documented, numbers of personnel involved in the response, and quantities of oily material removed from shoreline areas.

- **DFO ACTIVITY SUMMARIES**, which described the results of surveillance and reconnaissance activities, spill trajectory information and planned activities for the following day.

- **ENVIRONMENTAL IMPACT SUMMARY** by the environmental impact assessment team, which gave up-dated results of dead bird counts, winter seabird concentrations, and natural resource concentrations and other environmental sensitivities in relation to oil locations.

- **DOE SITUATION REPORTS**, which summarized information on the response activities and impacts of the spill obtained by its own staff and those of its environmental consultant, CCG, DFO, MOE, Parks Canada, the Nuu-Chah-Nulth Tribal Council and volunteer groups.

3.1 Assessment Activities

3.1.1 Daily Assessments

During the initial first two weeks of oil strandings on the west coast of Vancouver Island and during subsequent new oiling and re-oiling events, the coordinators of the Assessment Team prepared daily assessment reports for submission to REET. These reports focused on the locations of important ecological and aesthetic resources in relation to reported oil sightings. The Daily Assessment Reports also contained information obtained from participating government agencies including:

- observations of important winter seabird concentrations and evidence of impacts obtained by on-site personnel from CWS;

- locations of marine mammal sightings by DFO and Parks Canada (particularly sea otter colonies) and any evidence of impacts;

- the numbers of dead and oil-contaminated birds reported by Parks Canada staff and various volunteers involved in oil spill clean-up operations;

- projected oil trajectories based on analyses conducted by DFO scientists from the Institute of Ocean Sciences; and

- risk and sensitivity analysis.

Information presented in Daily Assessment Reports contributed to the establishment of clean-up priorities for submission to CCG each evening. The coordinators would also summarize activity plans of the Assessment Team for

the following day, and determine helicopter support requirements for surveillance, evaluation and assessment purposes.

3.1.2 Short-term Impact Assessment

Several projects and activities were initiated to determine the immediate or short-term impacts of the Nestucca oil spill on the biophysical environment of the west coast of Vancouver Island. Table 3-1 summarizes the immediate and short-term assessment activities and studies that were initiated by government in response to this accidental spill.

3.1.3 Long-term Impact Assessment

Longer-term research programmes will focus on the fate of oil in key environmental compartments and the effects of Bunker C from the Nestucca on valued ecosystem components. The overall objective of these investigations will be to quantify the impact of the Nestucca oil spill on the Canadian marine environment. Some of the longer-term studies have already been initiated, while others are in their early planning stages. Still others have only been proposed at this time and others are contingent on results of earlier studies. Table 3-2 summarizes many (but not necessarily all) of the longer-term studies that have been or may be initiated by the federal and provincial governments.

4.0 MOVEMENTS AND FATE OF NESTUCCA OIL ON THE WEST COAST

Because this and subsequent report sections make reference to numerous geographic locations along the west coast of Vancouver Island, Figures 4-1 and 4-2 show the names of these sites on computer-generated maps of Vancouver Island and the Barkley Sound region.

TABLE 3-1: IMMEDIATE AND SHORT-TERM ASSESSMENT ACTIVITIES AND STUDIES INITIATED IN RESPONSE TO THE NESTUCCA OIL SPILL

ACTIVITY OR STUDY	AGENCY
Daily records of dead bird counts by all participants in the response	Environment Canada (Canadian Wildlife Service)
Survey of winter bird concentrations in relation to oil locations	Environment Canada (Canadian Wildlife Service)
Characterization of the physical and chemical nature of NESTUCCA oil	Environment Canada (Environmental Protection)
Transect surveys and beached-bird surveys in the Trevor Channel-Bamfield-Pachena Bay area	Environment Canada (Canadian Wildlife Service)
Survey of sea lion haul-outs in relation to oil locations	Fisheries and Oceans (Science Branch)
Observations of sea otter behaviour and identification of possible oiling	Fisheries and Oceans (Science Branch)
Subtidal inspections of important shellfish habitats by SCUBA	Fisheries and Oceans (Fisheries/Science Branches)
Beach surveys of herring spawning, clam and salmon rearing habitats	Fisheries and Oceans (Fisheries/Science Branches)
Organoleptic testing of molluscan and crustacean shellfish	Fisheries and Oceans (Fisheries/Inspection & Special Services Branches)
Examination of herring spawning habitats by SCUBA	Fisheries and Oceans (Fisheries/Science Branches)
PAH analysis of selected shellfish tissues	Fisheries and Oceans (Inspection and Spec. Serv. Brs.)

TABLE 3-1: IMMEDIATE AND SHORT-TERM ASSESSMENT ACTIVITIES AND STUDIES INITIATED IN RESPONSE TO THE NESTUCCA OIL SPILL (Continued)

ACTIVITY OR STUDY	AGENCY
Offshore water column and benthic survey for oil along the west coast of Vancouver Is. aboard the J.P. Tully	Fisheries and Oceans and Environment Canada
Commercial crab and fish sampling and interviews with fishermen	Fisheries and Oceans (Fisheries/Science Branches)
Aerial surveys and remote sensing of oil contaminated areas	Fisheries and Oceans (Science Br.) Environment Canada (Environmental Protection and Canadian Wildlife Service)
Daily surveillance, cataloguing and mapping of oiled beaches, and preparation of a searchable computer database of oil observations	Environment Canada (Environmental Protection) Ministry of Environment (Planning and Assessment)
Incorporation of oil observations and resource information into a Geographic Information System (QuickMap) and preparation of large-scale maps of oil distribution in relation to biological resources and harvest data	ESL under contract to the Department of Environment and Ministry of Environment

Bunker C oil from the Nestucca moved north past Cape Flattery, Washington and stranded at Carmanah Point in British Columbia on 31 December 1988. Subsequent movements of oil along the west coast of Vancouver Island were longshore, and driven by a combination of winds and currents at an average velocity of 0.8 kph. Within 17 days of its initial stranding on the southeast tip of Vancouver Island, oil was detected in the Triangle Island Group and along the shores of Cape Scott on the northern tip of Vancouver Island (Figure 4-4).

TABLE 3-2: LONGER-TERM RESEARCH PROGRAMMES INITIATED OR PROPOSED TO DETERMINE THE FATE AND EFFECTS OF OIL FROM THE NESTUCCA IN THE CANADIAN MARINE ENVIRONMENT

ACTIVITY OR STUDY	AGENCY
Investigation of the fate of oil buried in sands and gravels of ten beaches on the west coast of Vancouver Island	Environment Canada Ministry of Environment
Herring spawn distribution and egg/larval survival	Fisheries and Oceans
Resource contaminant study - Detailed analysis to follow-up organoleptic tests conducted by Inspection and Special Services Branches (DFO)	Fisheries and Oceans
Analysis of crab stomach contents and studies of the depuration of hydrocarbons from Dungeness crabs	Fisheries and Oceans
Investigation of intertidal vegetation regeneration	Fisheries and Oceans
Investigation of the effects of intertidally and subtidally deposited oil on sea otter-urchin-algae ecology	Fisheries and Oceans
Periodic surveillance of sea otter populations at Sajo Point and in the Bunsby Islands area to determine potential oiling hazards and population status	Fisheries and Oceans
Physical and chemical changes to oil on beaches and in subtidal deposits during long-term weathering processes	Environment Canada
Oil contamination of grey whale feeding areas, crab habitat and shellfish growing areas	Fisheries and Oceans
Incidence of crab and crab trap oiling in closed and selected open DFO Statisical Areas	Fisheries and Oceans

TABLE 3-2: LONGER-TERM RESEARCH PROGRAMMES INITIATED OR PROPOSED TO DETERMINE THE FATE AND EFFECTS OF OIL FROM THE NESTUCCA IN THE CANADIAN MARINE ENVIRONMENT (Continued)

ACTIVITY OR STUDY	AGENCY
Use of crab gear and other methods to test for subsurface oil contamination of important benthic habitats	Fisheries and Oceans
Long-term persistence of tar balls in Pacific Rim National Park	Environment Canada (Parks Canada)
Long-term changes in tide pool community assemblages in important national park habitats	Environment Canada (Parks Canada)
Comparison of pre-spill and January 1989 winter seabird species distributions	Environment Canada (Canadian Wildlife Service)
Determination of the impact of the spill on seabird breeding colonies	Environment Canada (Canadian Wildlife Service)
Shellfish sampling for organoleptic analysis	Fisheries and Oceans
Effects of the NESTUCCA spill on sea otter habitat and populations	Fisheries and Oceans
Effects of the NESTUCCA spill on ground fish	Fisheries and Oceans

Locations of oil sightings and strandings have been transcribed to digitized computer map bases (primarily at scales of 1:40,000 or 1:50,000) for access by a Geographic Information System (QuickMap). Sample outputs from the GIS showing both the locations of oil sightings and resource and resource use information for areas along the west coast of Vancouver Island (Pachena Point to Cape Scott) are presented in Appendix D. The sources of oil sighting information included:

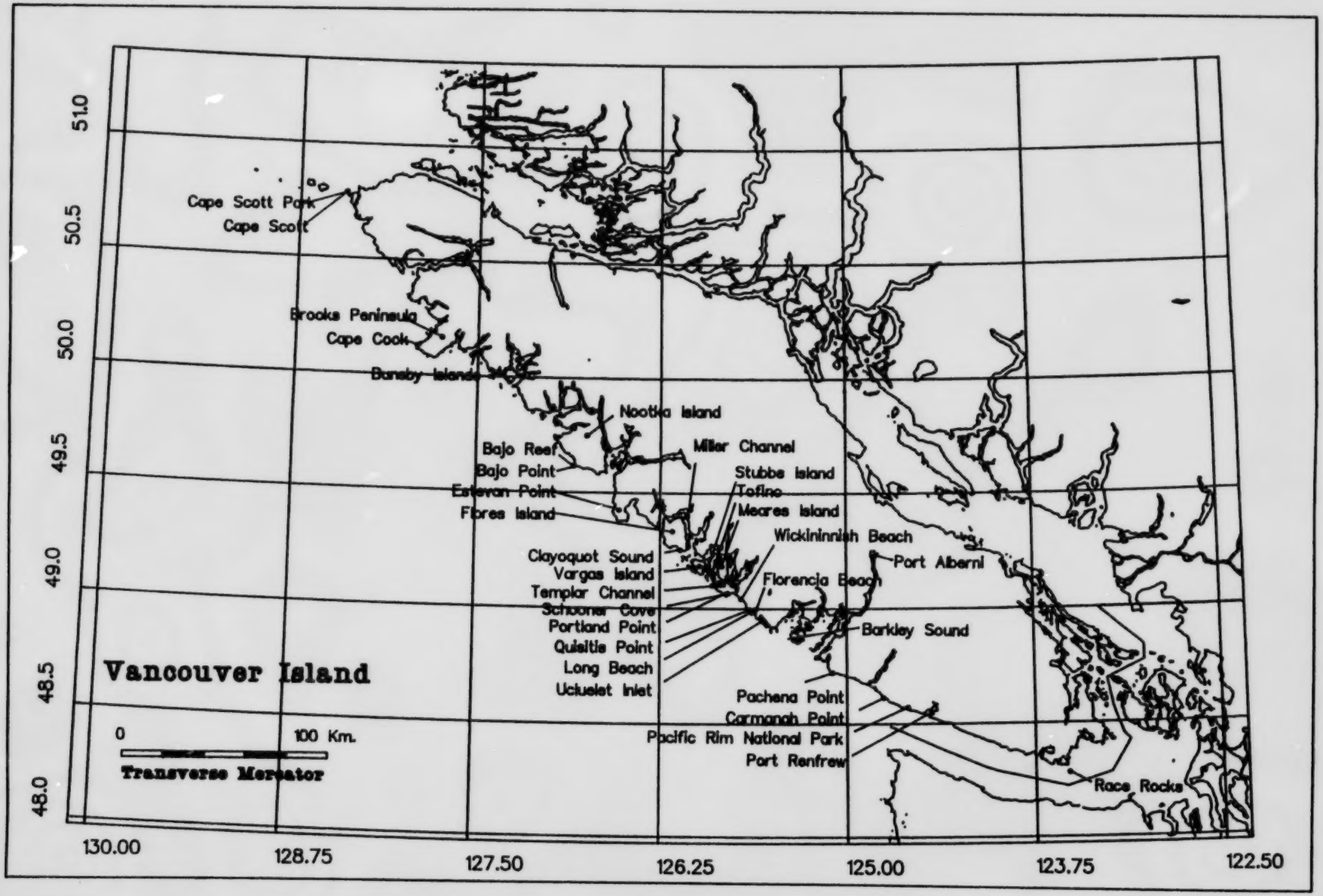


Figure 4-1: Map of Vancouver Island

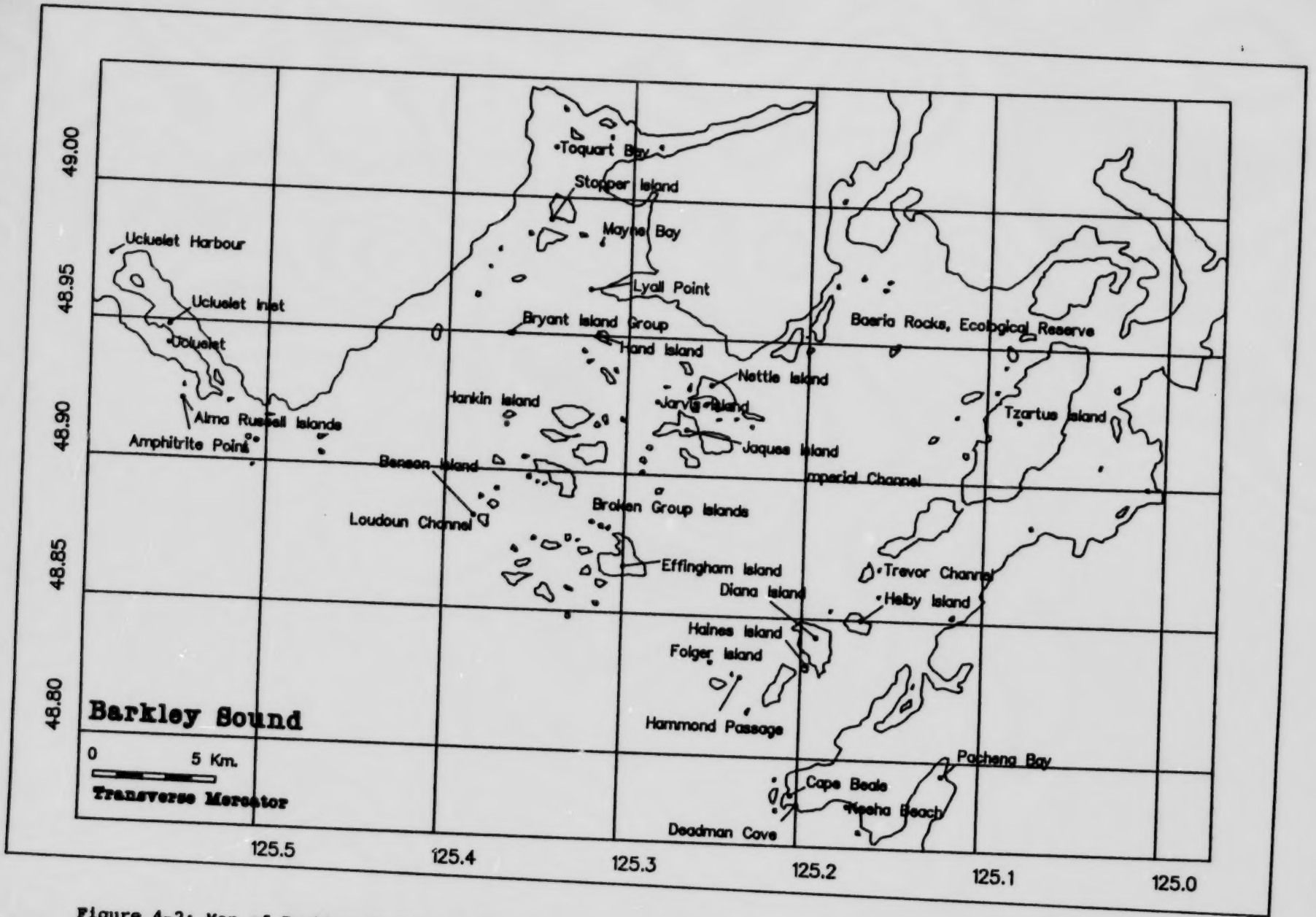


Figure 4-2: Map of Barkley Sound region

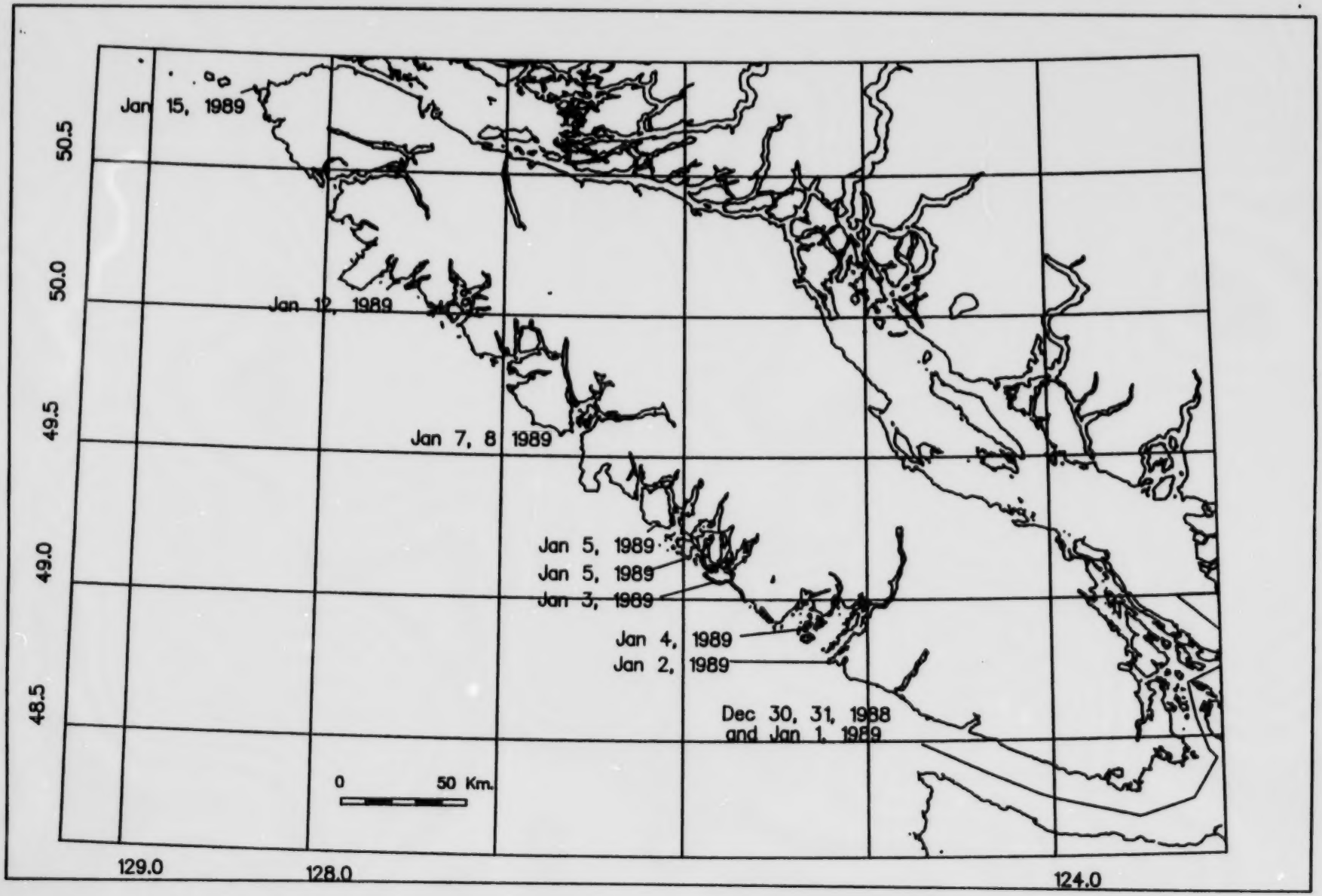


Figure 4-3: Dates and Locations of Initial Oil Stranding on the West Coast of Vancouver Island.

- DOT (Canadian Coast Guard)
- DOE (Conservation and Protection, Parks Canada, Canadian Wildlife Service, consultants on contract to DOE)
- DFO (aerial surveillance team, marine mammal team, dive teams, fishery and benthic ecologists and habitat protection specialists) from Pacific Biological Station (Nanaimo), West Vancouver Laboratory and Institute of Ocean Sciences (Sidney)
- DFO fisheries officers and patrol vessels
- observations from the cruise of the DFO research vessel J.P. Tully
- MOE (Planning and Assessment)
- Vancouver Aquarium
- Nuu-Chah-Nulth Tribal Council and Kwakiutl District Council
- Many local Indian bands
- Volunteer organizations (Provincial Emergencies Program, Friends of Clayoquot)
- Burrard Clean (clean-up contractor)
- private citizens

The Assessment Team used a classification system comprising five classes to describe the degree of oil contamination on shorelines. These classes have been included in the GIS input data and map outputs (Appendix D) when observations were available. Criteria for each class include:

Class 1 no visible oil on surface of rock or beach
no visible oil in subsurface sediments
no visible oil in or on logs

Class 2 sheen (rainbow oil) on surface of rock or beach
no visible black oil on rock or beach
thin (< 2 cm) cover of oil on logs or rocks

Class 3 sheen (rainbow oil) on surface AND brown or black oil
size of brown or black oil is 2 cm or less with occasional 14-20 cm diameter blobs

Class 4 surface oil cover on rocks and/or beach is thick (> 2.6 cm)
size of blobs is 25 cm or larger diameter
logs have blobs or oil cover > 2.6 cm thick

Class 5 continuous oil cover, not blobs, > 4.8 cm thick

Oil cover on shore was rated by Assessment Team participants as light (L), moderate (M) or heavy (H). Criteria for each rating include:

light
5 to 10 % of shore covered with sheen (rainbow oil)
brown/black oil blobs, 25 cm or larger diameter
no more than 10 blobs/m^2

moderate
brown/black oil blobs 25 cm or larger diameter
more than one blob/m^2
greater than 10 m of shore contaminated

heavy
brown/black blobs of 25 cm diameter or larger over more than 10 m of shore but not continuous oil cover

Locations of marine resources and resource uses have also been included in the GIS map database at the same scale as oil locations (Appendix D). Much of this resource-related information was already available in database files prepared for other ESL projects including shellfish data compiled for the Department of Environment and information relevant to the siting of aquaculture facilities from AquaBC (an application of the QuickMap GIS). However, new resource-related information was added to the database as part of this project, particularly the most recent information on the location of herring spawning areas from DFO, seal and sea lion haul-out sites, and native resource use information obtained from the Nuu-Chah-Nulth Tribal and Kwakiutl District councils.

The following sections describe the movements of oil along the west coast of Vancouver Island, the physical states of oil, the case history of oil contamination in Barkley Sound, and re-oiling of the Long Beach unit shoreline areas during the weeks that followed the Nestucca oil spill.

4.1 General Movements and Extent of Oil Contamination

The sequence of oil stranding along the west coast of Vancouver Island is illustrated in Figure 4-3 and summarized in Table 4-1. The linear distance between Carmanah Point and Cape Scott is about 365 km. Given that it required 17 days for oil to reach the northern tip of Vancouver Island, the average rate of northerly movement of the oil mass spilled from the Nestucca was about 22 km/day. More detailed information on the sequence of oiling of the west coast of Vancouver Island is provided on the computer-generated maps contained in Appendix D.

TABLE 4-1: SEQUENCE OF OIL STRANDING ON THE WEST COAST OF VANCOUVER ISLAND

DATE	MOST NORTHERN OIL LOCATION
31-Dec-88	Carmanah Point, Botanical Beach
02-Jan-89	Pachena Point
03-Jan-89	Long Beach Unit, Florencia and Schooner beaches
04-Jan-89	Broken Group Islands, Barkley Sound
05-Jan-89	Flores and Vargas islands, Miller Channel
06-Jan-89	Imperial Channel
07-Jan-89	Bajo Point, south tip Nootka Island
08-Jan-89	Friendly Cove, Bajo Point, Bajo Reef
09-Jan-89	gale force winds, no observations
10-Jan-89	heavy deposits on Bajo Point
11-Jan-89	gale force winds, no observations
12-Jan-89	Mission Island Group, Kyuquot Village
13-Jan-89	Brooks Peninsula
14-Jan-89	Raft Cove
15-Jan-89	Cape Scott, Scott Islands
27-Jan-89	Goose Group of islands near Bella Bella

In general, oiling was confined to exposed outer shorelines (rocky headlands, beaches and cobble areas) of Vancouver Island from Sooke to Cape Scott. Little oil was transported into coastal inlets and fjords, and this may have been attributable to the estuarine circulation patterns that predominate in these areas. However, some oil was deposited on the seafloor near Quisitis Point south of Long Beach and along the bottom channels leading

from open water into Clayoquot Sound. Subsurface oil was rarely visible to SCUBA divers, but appeared on crabs, crab traps and eelgrass.

Preliminary estimates suggested that about 150 km of beaches and intertidal areas were contaminated to some extent with oil from the Nestucca, although only 2-3 km of shoreline were considered "heavily oiled" (i.e., Class 5 or 'heavy oil' cover as per the classification described earlier) by the joint federal-provincial assessment team. Traces of oil were reported on rocky islets along the mainland shores of Queen Charlotte Sound south of Banks Island (Rodway et al. 1989). Although observed on 27 January, this oil was thought to have stranded several days earlier (about 24 January). Chemical analysis of the oil in the DOE laboratory confirmed that it was from the Nestucca.

Prevailing currents and winds were the predominant forces causing the general northeasterly movement of oil from the Nestucca spill. The dominating influence of surface currents on movements of oil slicks is well documented (e.g., Clark and MacLeod 1977; MacKay 1984) and the net northerly movement of surface waters in the Vancouver Island coastal current (Thomson 1981) would probably have carried oil towards the shorelines of Vancouver Island. Winds may either reinforce or modify the trajectory of oil slicks, depending on their strength and direction. It has been shown that an oil slick will move at about 3 % of the wind velocity and is deflected slightly to the right of wind direction in the Northern Hemisphere due to the Coriolis effect (Fingas et al. 1978; MacKay 1984). During January, winds off the west coast of Vancouver Island were variable, but were often from the southwest or northwest and occasionally up to gale force (40+ knots) velocities, both of which would have tended to force oil towards the B.C. coast. Inshore currents may also influence oil movements.

Tides also influence the distribution of oil in coastal areas. Some of the oil present on the water surface within intertidal areas may strand as the tide recedes, while a larger portion of the oil may be transported back out to sea. As a result, the same oil masses may have

contacted a number of shoreline areas as they moved northward, leaving only a small percentage of oil within the intertidal zone with each stranding. In many cases, this stranded oil was also floated off the beach on subsequent rising tides, and then presumably moved out to sea and further up the coast of Vancouver Island. This deposition of oil on one tidal cycle and its subsequent removal on the next cycle has been documented on numerous occasions (e.g., Butler et al. 1973, cited in Clark and MacLeod 1977).

The high specific gravity of the Bunker C (1.018; Fingas 1989) from the Nestucca by the time it had weathered at sea and reached coastal areas of Vancouver Island likely influenced its distribution once it contacted shoreline areas. Given the high-energy nature of much of this region and the already high specific gravity of the Bunker C, some oil transported towards the shore may have been forced towards the seafloor within the surf zone, where it could have contacted and incorporated some sediments. This could have further increased the specific gravity of the oil and favoured its sinking in some nearshore areas adjacent to sandy beaches or within the trenches that connect offshore areas to inlets and fjords. This is the probable mechanism for the observed subtidal deposition of oil. It is possible that some of the re-oiling of beaches along the Tofino-Ucluelet coastline following storms was due to the presence of submerged rather than surface oil off these sandy beaches. A more detailed analysis of the capability of oil from the Nestucca to sink after incorporation of sediments from the seafloor is provided in a report prepared by the Environmental Emergencies Technologies Branch of DOE (Fingas 1989; Appendix C). Fingas (1989) reports that a sunken oil blob analyzed in Ottawa consisted largely of small (1-3 mm) angular gravel such as that derived from a beach, and this would account for the neutrally-buoyant oil found during some dive surveys.

4.2 Physical States of Oil

Oil from the Nestucca was observed in a variety of different forms in marine environments along the coast of Vancouver Island. The types of oil varied from thin sheens to heavy encrustations on rocks and logs, "patties" of

varying size and density, oil fouled in eelgrass and algal growth, and heavy black sticky oil adhering to crab traps and on the carapaces of Dungeness crabs. Unweathered Bunker C is a highly viscous product of the refining process and is characterized by a relatively small proportion of low molecular weight hydrocarbons (so-called "light-ends"), high specific and API gravities, and relatively high pour point, initial boiling and flash point temperatures (Fingas et al. 1979). Chemical weathering involves loss of these lighter fractions, leaving a progressively higher proportion of high molecular weight compounds. Bunker C from the Nestucca was at sea from 1-3 weeks before stranding in coastal areas of Vancouver Island and underwent substantial weathering during this period, despite the low air and water temperatures in January. All of the Nestucca oil samples analyzed by the Conservation and Protection laboratory were weathered to some extent, although in only one case (a sample from Queen Charlotte Islands) was the weathering so advanced as to preclude positive identification. From the time of the spill, the bunker fuel would have increased further in specific gravity and viscosity with the loss of light-ends through dissolution and particularly evaporation. The high sea state at the time of the Nestucca accident would have favoured these processes, as well as some dispersion of oil droplets into waters beneath the spreading and moving surface slick. Nevertheless, strong odour and visible sheens persisting through March indicated the retention of some proportion of lighter fractions during that period.

4.2.1 Oil on the Water Surface

Oil was present on the water surface in four different forms: (1) sheens; (2) discontinuous slicks; (3) near-continuous slicks; and (4) variable-sized "pancakes" or "blobs" usually surrounded by sheens. A sheen (silver in colour) is an extremely thin oil film (generally < 0.1 um thick), often only detectable under favourable light conditions and on a relatively calm water surface. Sheens were present in many areas, particularly during the period between 5 January and 10 January. After this early period, persistent sheens at specific locations such as Dicebox Island and Estavan Point provided evidence of oil droplets separating from subtidal deposits and

rising to the surface. A slick is a thicker film of oil (generally 0.15-2.0 mm thick) and is characterized by the presence of bands of colour (i.e., rainbow appearance). Most slicks observed in waters off the coast of Vancouver Island were discontinuous and relatively small. Near-continuous slicks were reported only within the Barkley Sound-Pachena Bay region during the period from 4 January to 16 January. Oil "pancakes" or "blobs" were more frequently observed from vessels rather than during aerial surveys.

4.2.2 Oil within the Water Column

Dissolved hydrocarbon levels would have been very low because: (1) Bunker C has very small amounts of the soluble, low-molecular weight fractions; and (2) some of these soluble light-ends had been lost from the oil sampled on B.C. shorelines, as shown by chemical analyses. On the other hand, small oil droplets and particulate oil were observed within the water column, but their concentration and contribution to total oil concentration were not determined. Oil droplets and finer particulate oil (< 100 um) would have been formed from both surface slicks and oil "blobs" because of the mixing energy in areas with surf or wave action. This can be a relatively long-term process as evident after the spill of a much greater volume of Bunker C from the tanker Arrow in Chedabucto Bay (Nova Scotia, 1970). Relatively high concentrations of dispersed oil were measured in the water column three months after this spill (Levy 1971, cited in Duval et al. 1981).

Three investigations conducted by groups participating in the assessment of the impacts of this spill confirmed the presence of oil within the water column. An offshore survey was conducted between 23 January and 1 February from the J.P. Tully over an extensive area from the Brooks Peninsula to Barkley Sound. Surface neuston and Clarke Bumpus nets were deployed during this cruise, while surface water samples were also collected to determine the presence of oil. Visual examination of these samples revealed possible traces of oil in 14 of 108 neuston net samples, although confirmation by chemical analyses is required. Water was also pumped from various depths in the water column and filtered for microscopic oil droplets; the results of analysis are

not yet available. In another component of the assessment, ESL's divers observed some neutrally-buoyant oil within the water column (4.5 and 7.9 m water depth, depending on the site) in Templar Channel and Father Charles Channel (Clayoquot Sound region) on 13 March. Oil was present in three forms: (1) globules about 2 cm in diameter; (2) oblong blobs about 7-8 cm long; and (3) flat pancakes approximately 20 cm across (Appendix B). The former marble-size globules were most prevalent, although the actual volume of oil present was relatively low and very little oil was actually observed during these SCUBA surveys. Further information regarding the nature of this oil was obtained from two tests conducted by the divers. The first was to take several marble-sized globules and measure their sinking rate in the water column to a depth of 4.5 m where they were originally located. This rate was 5 cm/sec and was consistent among globules. The second test was to determine the adhesiveness of the oil to vegetation, and it was noted that the oil would adhere to eelgrass but not kelp.

Limited sampling by DOE of nearshore surface water on February 10 and analysis by IR showed 200-2500 ug of hydrocarbons per litre of water. Results of more extensive water column sampling in the Stubbs Island - Long Beach area are not yet available.

4.2.3 Oil on Seafloor Sediments

Various dive surveys were conducted by members of the Assessment Team to determine any subtidal impacts of oil from the Nestucca. In addition, oil fouling of commercial crab traps and Dungeness crabs is evidence that oil reached the seafloor in some areas (Tofino-Ucluelet area and entrance to Clayoquot Sound). DFO divers examined the seafloor around oiled crab traps in the Stubbs Island area and found very little oil in that area even though crab traps and crabs had been contaminated. Divers contracted to DOE also observed only a few small droplets of oil in this area. The divers infrequently observed movement of small oil globules along the bottom, and it was suggested that crab traps were being subjected to a periodic "rain" of these particles. More extensive oiling of crab traps occurred off Long Beach

in about 12 m of water (20 January), but occurred down to 45 m. These traps appeared heavily oiled with black sticky oil globules and lumps, suggesting that the bottom was more extensively oiled in this area. Submerged oil was also rarely observed by divers near herring spawning areas within Barkley Sound. No significant subtidal deposits of oil were detected during the cruise of the J.P. Tully, although the sampling grid during this cruise was very coarse and restricted to areas where water depths were greater than 25-30 m. Possible traces of oil were detected in only 3 of 81 sediment samples collected with a Smith-McIntyre grab, but the chemical analysis needed to confirm these as oil has not been completed.

4.2.4 Oil on Shorelines

The physical characteristics and probable fate of oil stranding on shorelines along the west coast of Vancouver Island is discussed by shoreline type in Section 5.1 of this report.

4.3 Barkley Sound Oiling Sequences, 4 to 31 January, 1989

Movements of oil through Barkley Sound (including the Broken Group Islands) from 4 to 31 January are illustrated in the Map Folio presented in Appendix D. Surface oil was first observed at the east entrance to Barkley Sound on 4 January (Appendix D). A large, continuous oil slick occupied most of Keeha Bay and Hammond Passage (east of Folger Island). Point observations of stranded oil were also recorded at three shoreline locations in the Alma Russell Island group.

On 5 January, Parks Canada surveyed the Broken Group Islands from fixed-wing aircraft and by boat. A discontinuous oil slick was observed throughout the majority of the islands, while nearly continuous oil slicks were located at the southern and northeastern ends of the Group. The southern slicks were bounded by Raymond Island (north), Austin Island (east), Cree Island (south) and Combe Rock (west). Continuous oil slicks also surrounded Wouwer, Howell, Batley, Cooper, Moreton, Gilbert, Banke, Dicebox, Austin and

Raymond islands. In addition, numerous small unnamed islands and the west coast of Effingham Island were contaminated with oil. The northeastern slicks were bounded by Brabant Island (north), the east coast of Jarvis Island (east), the north coast of Turtle Island (south) and Hankin Island (west). Continuous slicks enveloped Hankin, Single Rock, Dodd, Willis, Walsh and the Tiny Group of islands and the northeast coasts of Turtle Island. The oil slick observed a day earlier continued to remain throughout Keeha Bay and parts of Pachena Bay. Four elliptically-shaped slicks, oriented north-south, were found in Mayne Bay and two others were reported in Loudoun Channel near the Bryant Island Group. A large, continuous slick was located inside Toquart Bay against the north end of Stopper Island, while another (oriented east-west) was observed at the mouth of Ucluelet Inlet and encompassed George Fraser and Chrow islands, Sykes Reef, and Great Bear and Alley rocks.

By 7 January, continuous slicks that may have originally been located in the Broken Group Islands had moved north to enclose the south coast of Brabant Islands, the south, west and north coasts of Lyall Point, and nearshore areas of Mayne Bay.

On 11 January, only the southern and northeastern islands of the Broken Group and the eastern entrance to Barkley Sound were contaminated by continuous oil slicks. Relatively thick slicks were observed along the Keeha Beach area of Keeha Bay. A large, elliptical slick with an east-west orientation was reported immediately south of Wouwer, Howell and Cree islands. Surface oil was also present in the north end of Effingham Bay, along the east coasts of Gilbert Island, the northeast tip of Dempster Island, the north end of Mullins Island, and the east and west coasts of Keith Island.

During reconnaissances conducted from 13-16 January, it was reported that slicks and sheens persisted in the southern Broken Group Islands (Wouwer, Howell, Dicebox and Cree). Two sheens were observed at the north and east ends of Turret Island and in Sechart Channel between Hand and Prideaux islands. Continuous slicks surrounded the perimeters of Haines Island, the west, south and east tip of Diana Island and the northwest tip of Helby Island

in Trevor Channel. A large slick persisted at the mouth of Ucluelet Inlet and enveloped Beg Island and the southern foreshores of the entrance to Ucluelet Harbour.

On 20 January, continuous oil slicks were observed in the west cove of Pachena Bay and throughout Keeha Bay from Deadman Cove through Keeha Beach (Appendix D). This oil distribution was similar to that noted on 4-5 January and remained in this area until 23 January. On 20 January, continuous oil slicks were also reported along the northwest coast of Edward King Island and Kirby Point on Diana Island.

By the end of January, extensive clean-up and natural dispersion of stranded oil had occurred within Barkley Sound. In the Broken Group Islands, stranded oil was removed from the following locations: the southeast bays of Wouwer Island; the two east bays of Howell Island; the west bay of Dice Box Island; the northeast tip of Austin Island; three bays on the east side of Gilbert Island; two bays north of Meares Bluff, Effingham Island; the east bay of Benson Island; the southeast tip of Turtle Island; the north end of Dodd Island; an unnamed island between Jarvis and Jaques island; two locations of the northeast tip of Nettle Island; and the northern end of Glen Island.

Stranded oil also occurred at various locations on the Ucluth Peninsula and within Ucluelet Inlet. Specific locations are shown in Appendix D, and include: Amphitrite Point and an unnamed bay to the north; the south end of George Fraser Islands; the northeast tip of Beg Island; and at nine locations on the north shore of the entrance to Ucluelet Inlet.

4.4 Sequence of Re-Oiling of the Long Beach Unit

Re-oiling was predicted on 11 January when SCUBA divers contracted by DOE verified news reports of sunken oil in the Stubbs Island area. On 12 January and repeatedly until 28 January, many shorelines were re-oiled after having been initially cleaned. A general incidence of re-oiling also occurred

on 7 March in Ucluelet-Tofino area and along the south coast of the Brooks Peninsula.

TABLE 4-2: RE-OILING OF THE LONG BEACH UNIT BY CLASS AND INTENSITY
(Refer to Classification System in Appendix A; re-oiling is inferred when the classification is raised such as from 2 to 3 or Moderate to Heavy)

DATE	FLORENCIA B.	SCHOONER B.	LONG B.	WICK. B.	COMBERS B.	SOUTH B.
09 01						4/H
10 01						
11 01	slick	3-4/M				
12 01			4/M-H		4/M-H	3-4/M-H
13 01	3/L-M	2/L	2/L	3	3/M	slick
14 01	3/M	2/L	3/L	3/M-H	3/M-H	
15 01	3/L-M	2/L	3/M	4/L-M	4/L-M	3/L-M
16 01	3/M-H	3/L-M-H	4/M-H	4/M-H	4/M-H	3/M-H
17 01	3/M	3/L	4/L-M		3-4/M	3/L
18 01	3/M	2-3/L-M	3-4/M-H	4/L	3/M-H	
19 01	3/L-M	2-3/L-M	3/L	3/M-H	3/M-H	
20 01	4/M	3/L	2/M	3/L	3/L	3/L
21 01	2/L	2/M	3	2/L	2/L	
22 01	2/L	2/L	2/L	2/L	2/L	
23 01	2-3/L	2/L	2-3/L	2-3/L	2	2/L
24 01	2-3/L-M	3/M-H	2-3/L	2-3/L	2-3/L	
25 01	3-4/L	3/L	3/L	3/L	3/L	
26 01	2-3/L-M	3/L	3/L	3/L	3/L	
27 01	2-3/L-M	2-3/L	2-3/L	3/L	3/L	3/L
28 01	2-3/M	2-3/L	2-3/L	3/L-M	3/L-M	3/L
29 01	2/L	2/L	2/L	2/L	2/L	2/M
30 01	2/L	2/L	2/L	2/L	2/L	2/L
31 01	2/L	2/L	3/L	2/L	2/L	2/L
01 02	2/L	2/L	2/L	2/L	2/L	2/L
02 02	2/L	2/L	2/L	2/L	2/L	2/L
03 02	2/L	2/L	2/L	2/L	2/L	2/L
04 02	2/L	2/L	2/L	2/L	2/L	2/L
05 02	2/L	2/L	2/L	2/L	2/L	2/L
06 02	2/L	2/L	2/L	2/L	2/L	2/L
07 02	2/L	2/L	2/L	2/L	2/L	2/L
08 02	2/L	2/L	2/L	2/L	2/L	2/L
09 02	2/L	2/L	2/L	2/L	2/L	2/L
10 02	2/L	2/L	2/L	2/L	2/L	2/L

Data from the Long Beach Unit in Pacific Rim National Park are presented as an example of re-oiling sequences because regular inspections by Parks staff provided the most complete record. It was first affected by stranded Bunker C on 3 January. Most beaches were persistently re-oiled until at least 7 March. The classification and intensity of oil reported on various beaches within the Long Beach Unit are summarized in Table 4-2, based on the rating system provided by E. Owens (Appendix A).

5.0 PHYSICAL, BIOLOGICAL AND RESOURCE USE IMPACTS

5.1 Physical Fate

This section discusses what was known at the end of March 1989 regarding the probable physical fate and effects of Bunker C that stranded in different shoreline habitat types on the west coast of Vancouver Island. Where possible, an attempt is made to relate the class and state of oil described earlier in Section 4.1 to its physical effects on the shoreline. Most oil contamination was confined to exposed outer shorelines (rocky headlands, beaches and cobble areas) of Vancouver Island, with substantially less oil being transported into coastal inlets and fjords. These outer coast areas are very high energy environments throughout most of the year, primarily due to wave action and, to a far lesser extent, longshore and tidal currents. In contrast, there is less energy in some of the more sheltered inlets and sounds, particularly in the lee of islands and within areas such as Mayne Bay and Toquart Bay within Barkley Sound that is sheltered from direct exposure to the open ocean by numerous islands. These differences in exposure and energy had implications to the behaviour of oil stranding on shorelines, and will also have considerable bearing on its fate over the medium and long term. In addition, there is a general tendency for greater numbers and sizes of logs and other wood debris to be found on the exposed outer coastal areas. This also has implications to the physical effects and fate of stranded oil.

Oil contacted shorelines along the coast in surface layers varying in thickness from very thin sheens to thick mats containing highly viscous oil pancakes and globules. The oil category observed on most contaminated shorelines was recorded by members of the Assessment Team and is indicated in conjunction with each oil sighting in the Map Folio presented in Appendix D. There was some speculation that submerged oil reached the shores of Vancouver Island because surface oil masses or slicks were not usually detected during aerial surveys of offshore areas. However, Bunker C from the Nestucca could not have been transported to coastal B.C. waters beneath the surface because its specific gravity at ambient water temperatures of 0 to 5°C (1.0181 to 1.0186; Fingas 1989; Appendix C) was less than that of seawater collected at the same sites (1.0229 to 1.0232) and therefore would float. It could, however, sink or become neutrally-buoyant at some depth within the water column once it contacted beach sediments and this granular material became incorporated within the oil, as shown by the analysis conducted by DOE (Fingas 1989). Oil masses that had contacted sediments subtidally within the surf zone or had stranded intertidally on beaches and then were subsequently transported back to sea could move beneath the surface. Depending on the amount of granular material incorporated within such oil masses (and therefore their specific gravity), they could then either: (1) sink almost immediately to the seafloor; or (2) sink to a depth where it is neutrally-buoyant (which could still be the water surface if only a small amount of sediment was present in the oil). In the former circumstances, the ultimate fate of sunken oil masses would depend on a variety of factors but could include burial within the seafloor sediments and redistribution to adjacent areas (Duval, ed. 1985). In the latter situation, neutrally-buoyant oil masses could be: (1) transported within the water column by currents to other areas; (2) washed ashore; or (3) physically separated into two oil globules, with the higher density (sediment-laden) oil sinking to the seafloor and the lighter portion rising to and floating on the water surface (likely surrounded by a small oil slick or sheen).

Oil may also sink as a result of other processes that increase its specific gravity. Clark and MacLeod (1977) report that processes that increase the specific gravity and cause petroleum to sink are: (1) evaporation and dissolution of the low molecular weight hydrocarbons; (2) degradation and oxidation of components of the oil; (3) formation of dispersed particles and subsequent agglomeration of these particles; (4) absorption and adsorption of the oil by particulate matter; and (5) uptake of sea water during emulsification. There is both direct and indirect evidence of the sinking of Bunker C following previous spills. For example, Dennis (1959, cited in Clark and MacLeod 1977) reported that about 6400 tons of heavy fuel oil sank in cold water off the eastern U.S. and reappeared at the surface later under warmer conditions. A phenomenon similar to that noted after the Nestucca spill was observed following a major Bunker C spill at the entrance to San Francisco Bay in 1971. Some of the oil globules were neutrally-buoyant in the near-bottom layer of water in the bay, and this layer moved independently of the surface oil slicks, stranding ashore on different beaches some distance away from beaches contaminated by floating oil (Conomos 1975, cited in Clark and MacLeod 1977). Neutrally-buoyant oil sinking to the pycnocline is of greatest concern in estuarine areas where saline, oceanic water at depth moves into the estuary toward the river mouths to replace the saline water which is entrained or mixed upward into the brackish surface outflow (Clark and MacLeod 1977).

In coastal areas, there is also a high potential for sinking of oil following interaction with suspended inorganic and organic material in the water column. Clark and MacLeod (1977) and others have reported the physical or chemical sorption of particulates to oil present in dispersed form within the water column. Such materials include organics, clays, calcite, aragonite, glacial flour, and siliceous sand grains. In rough seas, these materials are mixed with the dispersed oil (particularly in shallow areas), and the particles with sorbed petroleum eventually settle to the bottom during calm seas (Clark and MacLeod 1977). The National Academy of Sciences (1975, cited in Clark and MacLeod 1977) indicate that silt particles have a density of about 2.65 and, therefore, only small amounts need to be incorporated with the

petroleum to produce an oil-silt combination denser than sea water. Sinking of oil through this process almost certainly occurred following the Nestucca spill in surf and nearshore zones with high suspended particulate loads. Sorbed oil present on the seafloor is unlikely to be detected during dive surveys because of the small size of oil particles. In addition, significant lateral spreading of sedimented petroleum can occur for at least several months (Kolpack et al. 1971 and Blumer and Sass 1972, cited in Clark and MacLeod 1977) and can have serious impacts on some benthic and intertidal organisms once it becomes incorporated in the upper layer of the sediments (Shaw et al. 1976, cited in Clark and MacLeod 1977).

5.1.1 Sand Beach Habitats

Oil was stranded on both exposed and sheltered sand beaches on Vancouver Island following the Nestucca spill. Examples of the former include Long Beach and Combers Beach in Pacific Rim National Park, whereas an example of a protected sand/gravel beach that received significant amounts of oil is on Dicebox Island (Broken Group, Barkley Sound). On exposed sand beaches such as Combers, numerous logs and other wood debris are present and when accompanied by high sea states, the action of waves and moving logs can drive oil into the substrate. Even on those days when the tidal amplitude was lower and oil was not transported as high into the intertidal zone, there was sufficient wave energy on these exposed sand beaches along the outer coast to cause oil to become mixed with the sediments.

Oil in the form of mats was observed frequently on sandy beaches, and continuous wave action often caused oil mats not removed by clean-up personnel to become mixed with sand and then incorporated into the substrate. Liquid oil does not readily penetrate wet or fine-grained sands, but wave and surf action may throw fresh sand over oil deposits (Clark and MacLeod 1977). Oil may also penetrate burrows created by invertebrates. The presence of oil beneath the surface on beaches within the Long Beach Unit was evident as early as 8 January when small oil sheens were observed at the surface of burrows created by bivalves and crustaceans.

The depth of oil penetration in exposed and sheltered sandy beaches in not known, although it is at least 30 cm in some areas. As part of this project, substrate samples were collected during the period from 14-16 January for analysis of oil content. Two transects were sampled on each of ten beaches (Ahous, Bajo, Brooks, Combers, Dicebox, Florencia, Mayne, Pachena, Wickaninnish and Wouwer). Samples were collected in high, mid and low tidal zones, from the beach surface, and at 15 cm and 30 cm depths into the substrate. A second sampling programme was completed at most of the same sites and substrate depths in late March. Depending on oil concentrations found in March, additional surveys may be scheduled for May and August 1989. The results of these sediment sampling programs will be discussed in the Final Impact Assessment prepared for the Nestucca oil spill.

5.1.2 Mud Beach Habitats

Mud flats occur in sheltered areas on the west coast of Vancouver Island where the slope of the beach is very gradual and surface water fails to drain completely from the intertidal zone. Outgoing tidal currents in such areas have a low velocity and organic material thereby settles out of the tidal streams and remains on the mud flats. Mud flats have abundant fauna both above and beneath the surface.

Mayne Bay, located at the northwest end of Barkley Sound and east of Stopper Island, is an example of a low-energy, protected mud (silty sand and clay) flat affected by oil following the Nestucca spill. The porosity of this type of substrate is usually less than that of fine to coarse sand areas, and oil penetration likely occurred primarily through holes in the mud created by the siphons of clams and possibly burrowing activities of ghost shrimp, as opposed to burial of oil masses due to wave energy and the movement of logs and smaller pieces of wood debris.

In contrast to the oil mats observed on exposed sand beaches, such thick layers of oil were uncommon on mud flats such as Mayne Bay. Most oil probably reached this area as surface sheens or slicks. In addition, at least

in the case of Mayne Bay, the oil tended to remain onshore and re-oiling was rare. The amount and fate of oil that stranded on other mud beaches on the west coast of Vancouver Island is largely unknown at present. Mayne Bay is included in the sediment sampling program described earlier to determine the long-term fate of oil in these habitats.

5.1.3 Rocky Shoreline Habitats

Most of the area affected by the Nestucca oil in B.C. consisted of exposed, rocky shorelines. Fortunately, this is the shoreline type that "self-cleans" most rapidly following oil spills due to the high wave energy environment and the resistant substrate (Duval et al. 1981).

On rocky shores, deposition of slicks and finely-dispersed oil is often confined to the "algal felt" in the lower intertidal zone and to pores in the rock surface (Clark and MacLeod 1977). Tidal flushing removes considerable oil over a period of up to several months, while additional residues are removed by erosion of oil-contaminated dead algae, grazing of intertidal invertebrates, or biological uptake by flora and fauna (Spooner 1969 and Clark et al. 1973, cited in Clark and MacLeod 1977). Most Bunker C deposited on rocky shorelines of the exposed coast was removed relatively quickly by wave action, while oil in more protected areas was removed over a more prolonged period. Persistent oil deposits may occur in rocky shorelines with a relatively low slope, where oil becomes stranded and bonds to the substrate by partial melting (National Academy of Sciences 1975, cited in Clark and MacLeod 1977). The other region where oil may persist is in backshore environments above the high tide mark. This was observed after the grounding of the General M.C. Meigs off the Washington coast in January 1972. Navy Special Fuel (similar to Bunker C) was still observed in rock crevices in the form of a tough weathered layer three years after this spill (Clark et al. 1975, cited in Duval et al. 1981).

The exposed, rocky shoreline of Wouwer Island in the Broken Group Islands was heavily oiled. As the tide advanced and receded, large amounts of oil were deposited in tide pools and covered logs present in the intertidal zone. Wouwer Island required a concerted clean-up effort, including the burning of logs. All categories of oil described earlier in Section 4.1 were observed on either exposed or protected rocky shorelines on the west coast of Vancouver Island. Re-oiling also probably occurred in many areas, particularly in the Broken Group Islands, but was not as apparent as the re-oiling that occurred on the sandy beaches within the Long Beach Unit.

The protected, rocky shorelines of Vargas and Flores islands (Clayoquot Sound) and several islands of the Broken Group in Barkley Sound were also contaminated with Bunker C. In mid January, oil was still visible in tide pools and on the protected shores of some of these sites. However, by mid February, manual and natural cleaning had removed most of the visible contamination. The presence of oil in tide pools is a significant area of concern because it can: (1) decrease the amount of light entering the water, thereby affecting photosynthesis by tide pool algae; (2) reduce oxygen exchange through diffusion at the water-air interface; and (3) increase water temperatures by virtue of the tendency for oil to absorb heat from the sun and transfer this to underlying waters (Nelson-Smith 1973, cited in Clark and MacLeod 1977).

5.1.4 Large Cobble Beach Habitats

Cobble beaches are covered with loose stones and small boulders, which are mixed in a matrix of mud and sand. Bajo Point, located on the southwest coast of Nootka Island, is an example of a cobble beach that received heavy oiling as a result of the Nestucca spill. This beach type is widespread on the west coast of Vancouver Island; Bajo Point is unique only in that an offshore reef provides some protection from wave action , and is the habitat of a sea otter colony.

Oil was initially deposited at Bajo Point on 7 January as a thick (<= 15 cm), continuous covering (Class 5) over a length of approximately 50 m of the high intertidal zone. Within a few days, during which time clean-up was initiated, redistribution by high tides had extended the length of beach heavily contaminated to about 300 m. Oil had also percolated, or had been drawn by tidal pumping, at least 1 m into the gravel substrate. By early February, scattered blobs of oil and oiled debris extended approximately 3 km north, although the zone of heavy contamination had by then decreased to about the original 50 m area due to natural and manual cleaning. In mid March, a severe storm threw up a 2 m, continuous covering of kelp, eelgrass and other debris, effectively halting further clean-up activity. At this time small amounts of crusted oil residue were evident on cobbles and sheens were still highly visible in ground water percolating from the high intertidal zone.

5.1.5 Salt-Marsh Habitats

The high sensitivity of salt-marsh habitats to oil spills has been documented on numerous occasions, in part due to the persistence of oil in these areas and their importance as critical habitat for numerous fish and bird populations (Duval, ed. 1985). The biological implications of oiling of salt-marsh habitat are discussed later in this report (Section 5.2.1).

At the time of writing of this report, two salt marshes were known to have been oiled at Friendly Cove and Estavan Point.

Friendly Cove is located at the southern tip of Nootka Island. Extensive quantities of oil entered the lagoon on 8 January, and on the following day both CCG and volunteer clean-up personnel initiated restoration of the salt marsh. Oil covered an area about 100 m long and 20 m wide along the channel that connects the lagoon to the sea, and was several centimetres deep throughout much of the salt-marsh habitat. In fact, oil coverage of this area was so extensive that 30-40 bags of oiled vegetation was removed per hour by the 25+ member clean-up crew. The lagoon itself was apparently not oiled. All shoreline restoration techniques were manual and largely involved use of

shovels and absorbent towels. The removal of oiled vegetation required four days and involved removal of the top 4 cm of marsh vegetation, leaving only a light oil sheen.

A second saltmarsh north of Estavan Point (Perez Rocks) received several blobs of oil 0.5 to 2.0 m in length. No restoration was done, and the site was measured and photographed for possible future study.

It is very likely that oil is still present within sediments of the contaminated area of these locations, and may persist in this habitat for several years, given the results of studies initiated after past oiling of salt marshes in Canada and elsewhere (Duval et al. 1981).

5.2 Biological Effects

The following sections describe the documented impacts of the Nestucca oil spill on biological resources of the west coast of Vancouver Island. It is emphasized from the outset that this is a preliminary assessment and that a number of studies have been planned or initiated by government to more fully evaluate the longer-term impacts of the incident (Section 3.1.3). The results of most of these investigations will be reported by various government departments. In addition, a final summary of the impacts of the Nestucca Spill is planned for early 1990 once the results of many of these studies are available.

5.2.1 Plant Communities

(a) Marine and Terrestrial Plant Communities (excluding Salt-Marsh)

In general, the immediate effects of the Nestucca oil spill on marine and terrestrial plant communities are not well documented, although some anecdotal evidence of damage is available. For example, a number of oil sighting reports refer to "an oily mat of kelp" and "oil-fouled eelgrass" which washed up on beaches and rocky shorelines. SCUBA divers noted that the

oil moved freely through anchored kelp but adhered readily to eelgrass (Zostera maritima). Experiments conducted by ESL's divers also demonstrated the adherence of neutrally-buoyant bunker globules within the water column to eelgrass but not kelp (Appendix B). The eelgrass beds near Stubbs Island were sufficiently oiled to warrant removal of contaminated eelgrass to prevent consumption by geese.

The effects of the Nestucca spill on benthic algae have not, to this point, been documented. Laboratory studies have indicated that relatively brief exposures (3-6 h) of benthic macro-algae to low concentrations (3-4 ppm) of dispersed oil in the water column can reduce photosynthesis (Martin, in Duval, ed. 1985). However, past oil spills have only infrequently caused impacts on benthic algae (Duval et al. 1981). Similarly, Cross et al. (1983) found that experimental oil releases during the Baffin Island Oil Spill (BIOS) did not affect the biomass of dominant algal species.

The Nestucca spill resulted in some mortality and damage to plants within the intertidal zone. Much of the oil-contaminated debris removed by clean-up crews during shoreline restoration programs was intertidal algae (primarily Fucus spp.). Mortality may have been attributable to: (1) coating and suffocation; (2) dislodging of plants in heavily contaminated areas due to the added weight of stranded oil; (3) chemical toxicity of the oil; and (4) damage or removal during the clean-up response (Martin, in Duval, ed. 1985). Dislodging due to the oil's weight was considered unlikely in this case, however, because intertidal plants in this environment are well adapted to high wave surge energy. Based on experience from past spills (Duval et al. 1981), the greatest losses of intertidal algae would have occurred in rocky rather than sandy habitats, as well as in those areas where either the entire intertidal zone was coated with oil or oil stranded in upper intertidal areas over successive tidal cycles (i.e., where re-oiling occurred).

Some oil was transported into backshore environments (i.e., above the intertidal zone), including some National Park beach environments, by wave action and activities of clean-up personnel. The extent of such contamination was minimal.

Duval et al. (1981) examined the biological impacts of 100 oil spills that have occurred throughout the world since the mid 1950s. Twenty-nine of these spills involved loss of either Bunker B or Bunker C, and of this number, seven resulted in damage to either intertidal algae or surfgrasses. Spills that occurred in the Pacific Northwest and resulted in impacts on plants were Irish Stardust (Alert Bay, 24 January 1973, 470 000 L of Bunker C) and General M.C. Meigs (near Cape Flattery, 9 January 1972, 160 000 L of Navy Special fuel), while the Arrow spill on Canada's east coast (Chedabucto Bay, 4 February 1970, 11 200 000 L of Bunker C) also damaged intertidal plants. Mortality and detachment of Fucus resulted from the Irish Stardust spill, while studies conducted three months after the event suggested that some attached algae was initially smothered and damaged by the Bunker C (Green et al. 1974, cited in Duval et al. 1981). Kelps (Laminaria) were severely damaged in areas adjacent the General M.C. Meigs spill, and bleaching of photosynthetic pigments was noted in several species of red and green algae. Plant species also retained oil for up to one year after this spill, but recovery of affected communities was essentially complete after 32 months (Clark et al. 1975; 1978, cited in Duval et al. 1981). The Arrow spill, which covered 300 km of beach in shallow, low-energy environments (Chedabucto Bay), resulted in relatively severe and long-term damage to intertidal algae. The greatest initial mortality of algae was the loss of Fucus that occurred in the lower intertidal zone, while other algal species were virtually eliminated from heavily-oiled areas within the mid tide zone and had still not recovered to their former abundance two years after the accident (Thomas 1973, cited in Duval et al. 1981). Algal biomass was still less abundant than in unaffected control areas six years after the Arrow spill (Vandermeulen and Gordon 1976, cited in Duval et al. 1981). This degree of impact would be very limited in extent in the Nestucca spill, where only some 2 km of beach was heavily (Class 5) contaminated, most of it on exposed, high-energy shorelines.

(b) **Salt-Marsh Vegetation**

As indicated earlier in Section 5.1.5, the salt-marsh habitat within Friendly Cove on Nootka Island was extensively contaminated with Bunker C from the Nestucca and required an intensive clean-up effort including the cropping of several centimetres of dry (previous season's growth), oiled vegetation. The Duval et al. (1981) review of past spills indicated that marsh grasses can be severely affected by oil contamination and can require many years to recover. This is because of the tendency of oil to penetrate and persist in the sediments, thereby resulting in long-term toxic effects as a result of the uptake of petroleum hydrocarbons through the root systems of these plants (Martin, in Duval, ed. 1985). Owens (1977) has indicated that salt-marsh habitats are the most sensitive coastal environments to oil spills, and that inappropriate clean-up techniques can accentuate the adverse impacts of spills on these communities.

The only past west coast bunker spill that had documented impacts on salt marshes was the Irish Stardust, while the Arrow and Golden Robin (Dalhousie Harbour, 30 September 1974, 330 000 L of residual fuel oils similar to Bunker C) spills on Canada's east coast also affected these sensitive habitats. Green et al. (1974, cited in Duval et al. 1981) reported that emergent grasses were matted together with oil but were still alive. After one year, these grasses were shorter than in adjacent uncontaminated areas, indicating that the oil affected growth but not survival. Saltmarsh cord grass showed evidence of damage up to two years after the Arrow spill (Thomas 1977, cited in Duval et al. 1981). The Golden Robin spill resulted in extensive contamination of salt-marsh habitat, with revegetation of oiled marsh ranging from nil to 50 % depending on the cleanup technique employed. Bunker C-like oil still persisted on marsh sediments after two years (Vandermeulen and Ross 1977, cited in Duval et al. 1981).

The presence of sheens after completion of the clean-up operations is evidence of some residual amount of oil contamination within the Friendly Cove salt-marsh. Several studies (e.g., Burns and Teal 1979) have shown that

oil remaining in marsh sediments may impede recolonization of salt-marsh grasses through the development of new roots and rhizomes. The chronic release of petroleum hydrocarbons from this area could also have relatively long-term (albeit localized) impacts on fish and wildlife populations that utilize the marsh during critical periods in their life history (e.g., as feeding habitats).

5.2.2 Planktonic Communities

(a) Phytoplankton

As is the case following the vast majority of oil spills, the impacts of this event on local phytoplankton populations were not examined. There have been no studies of the effects of past bunker spills in B.C. on phytoplankton.

The effects of past oil spills on phytoplankton were reviewed by Duval et al. (1981), who report that some spills (e.g., Amoco Cadiz) have caused local and brief decreases in the abundance or productivity of phytoplankton, while others (e.g., Tsesis, Ekofisk blowout) have actually increased primary productivity and the standing stock of certain species. The nature and magnitude of phytoplankton-oil interactions appears to vary with exposure circumstances.

(b) Zooplankton

The effects of Bunker C from the Nestucca on zooplankton populations were not examined. The most common zooplankton-oil interactions observed following spills have been physical contamination of these organisms and occasionally the presence of oil in their digestive tract (Duval et al. 1981; Trudel, in Duval, ed. 1985). Several authors have suggested that the ingestion of particulate oil by zooplankton and the subsequent sedimentation of this oil in faecal pellets may contribute significantly to the removal of hydrocarbons from the water column following spills (e.g., Conover 1971;

Sleeter and Butler 1982). Mortality of zooplankton has also resulted from at least three past bunker fuel spills in the world (Argo Merchant, Tsesis, and Sansenia; Duval et al. 1981). It is not known if zooplankton present in coastal areas affected by this spill either were physically contaminated by oil or contained any particulate oil in their gut, although this may be determined by microscopic examination of neuston samples collected during the cruise of the J.P. Tully.

5.2.3 Benthic Invertebrates

Benthic invertebrate populations could be affected by oil that reaches the seafloor through sinking or sedimentation (Section 5.1) or is present in a dispersed form within the water column in shallow subtidal areas. Both infauna (e.g., polychaetes, bivalve molluscs) and epifauna (e.g., crabs, sea urchins) can be affected by oil in this habitat (Martin, in Duval, ed. 1985). The effects of oil on these species are relatively well documented as a result of numerous laboratory and field investigations, including studies initiated after past spills (various authors cited in Duval et al. 1981).

(a) Infauna

There were no observations of the effects of the Nestucca spill on benthic infauna. Some mortality could have occurred in subtidal habitats adjacent to extensively oiled shoreline areas. Mortality of infauna has only been documented infrequently following bunker fuel (vs. diesel) spills. Large numbers of clams were killed following the Arrow spill as a result of: (1) predation after leaving their burrows to escape pooled oil; (2) suffocation when bunker oil clogged their burrows and prevented gas exchange; and (3) presumably toxic effects of the oil. In contrast, extensive examination of representative benthic fauna normally sensitive to oil failed to demonstrate even minor mortality resulting from the Vanlene spill (Barkley Sound, 14 March 1972, 390 000 L of Bunker B; Ages 1972 and Quayle 1974, cited in Duval et al. 1981).

Exposure may occur through direct contact with sunken oil masses or through ingestion of hydrocarbons present within the sediments or overlying water (Martin, in Duval, ed. 1985). The rate of recovery of locally-affected populations would be expected to vary with species and persistence of oil in benthic habitats. Detrital and deposit feeders such as polychaetes often require a longer period for recovery than filter feeders such as clams. Recovery would also require less time in exposed areas relative to sheltered habitats because oil is likely to be physically dispersed and degraded more quickly.

No long-term studies have been proposed by government to examine the infaunal component of benthic communities affected by the Nestucca spill.

(b) Epifauna

Crustaceans and echinoderms are the predominant taxonomic groups comprising the epifauna, with the former suffering greatest losses following past oil spills (Duval et al. 1981). Mortality appears to be highly dependent on the circumstances surrounding spills, and was not observed during subtidal dive surveys conducted by either DFO or ESL. Little oil was actually observed on the substrate during these surveys. For example, divers in the Stubbs Island area reported that oil globules were rarely observed along the bottom. However, the fact that near 100 % of the Dungeness crabs recovered from traps in Statistical Area 24 (off Quisitis Point and in the Florencia Bay and the Stubbs Island areas) were oiled indicates that exposure was significant in at least some habitats. A small percentage of crabs were still oiled at the end of March 1989, almost three months after Bunker C first reached the coast of Vancouver Island.

At times during January and early February, large numbers of dead crabs were reported on beaches in the Tofino area. DFO specialists responding to reports observed many shed exoskeletons, which is normal during moults, but not many dead crabs. There was also one report of large numbers of dead sea urchins along the West Coast Trail. Such mortalities occur naturally and

there have been no studies to determine if these observations were oil-related.

Although contamination of epibenthic invertebrates has been observed frequently following past oil spills, mortality was documented in only four of the 29 bunker spills reviewed by Duval et al. (1981). None of the west coast or eastern Canadian spills discussed in previous sections caused any detectable losses of crabs, starfish, sea urchins or other epibenthic invertebrates.

DFO collected samples of Dungeness crabs, red and purple sea urchins and sea cucumbers from areas with possible oil contamination. These samples were tested for the presence of hydrocarbons by organoleptic (taste/odour) analyses. A limited number of tissue samples were also analyzed to determine hydrocarbon constituents. In addition, staff from the Pacific Biological Station have initiated studies on the uptake and depuration of petroleum hydrocarbons from Bunker C by Dungeness crabs. Continuing studies will assist in assessment of both the short- and long-term impact of submerged oil on Dungeness crabs.

5.2.4 Intertidal Invertebrates

Intertidal invertebrates have often been one of the most visibly affected biological resources following oil spills (Duval et al. 1981), although effects on these fauna have often been difficult to distinguish from impacts on the entire intertidal community comprising both flora and fauna. The composition of this community is highly dependent on the nature of the substrate. The dominant taxonomic groups in rocky areas are gastropods (e.g., limpets, snails), sessile crustaceans (e.g., barnacles) and some bivalve molluscs (e.g., mussels), while bivalves (e.g., clams, oysters) and mobile crustaceans (e.g., amphipods) tend to predominate in sandy habitats.

The most common cause of mortality among intertidal species is smothering by thick layers of stranded oil, which interferes with feeding, respiration, and attachment to the substrate, and causes severe habitat disturbance (Martin, in Duval, ed. 1985). There is often complete elimination of intertidal fauna (particularly periwinkles, limpets, tube worms, barnacles, and crustaceans) in heavily-oiled areas (Duval et al. 1981). Observations of dead gammarid amphipods on oil mats indicate that some losses of intertidal fauna occurred in areas where oil stranded. Opportunities exist for recolonization of affected areas through recruitment once oil begins to naturally disperse from these habitats. This recovery process likely began within a few days of oiling of some exposed habitats, but may require longer in sheltered areas where oil persists. For example, in most cases where oil contaminated the rocky shores, it was often removed by wave action during the next or subsequent high tides. Impacts on intertidal fauna in these areas were likely very minor and possibly restricted to the more sensitive species noted above. In addition, most intertidal fauna reproduce during the spring and summer, and the associated larval settlement will greatly accelerate the recovery process already in progress through recolonization by natural dispersal of individuals from uncontaminated areas.

The oil spill case history literature indicates that contamination and usually some mortality of intertidal invertebrates has occurred when oil has stranded in shoreline habitats. Of the four west coast oil spills reviewed by Duval et al. (1981), the Vanlene, and Irish Stardust bunker spills resulted in mortality of intertidal fauna, while contamination but no losses of these organisms were observed following the Erawan spill near Vancouver, B.C. (English Bay, 25-September-1973, 312 000 L of Bunker B). Bunker B from the Vanlene was stranded primarily in the upper intertidal region, with lower intertidal organisms only receiving slight oil contamination. Organisms most seriously affected by the spill were Thaid gastropods, barnacles (where contamination was very heavy), periwinkles and limpets (Ages 1972, cited in Duval et al. 1981). Limpets and periwinkles were also seriously affected by the Irish Stardust near Alert Bay, while oil-contaminated amphipods with impaired mobility were also commonly observed (Green et al. 1974, cited in

Duval et al. 1981). Impacts on these species were evident for at least one year after the spill, particularly amphipods which showed marked differences in population densities. There is only limited information available on the impacts of the Erawan spill, although its overall impact on shellfish and other marine biota was described as slight (Center for Short-Lived Phenomena 1975, cited in Duval et al. 1981).

Some of the immediate impacts of the Nestucca spill on intertidal biota in terms of potential hydrocarbon uptake and tainting were examined by DFO. Pacific oysters, Olympia oysters, California mussels, bay mussels, gooseneck barnacles, and a variety of clam species (including manilla, littleneck and horseclams) were extensively sampled and tested by organoleptic analysis for the presence of contamination by hydrocarbons (tainting).

As indicated earlier in Section 3.1.3, DFO has either initiated or proposed a number of studies that will focus on determining the impacts of the Nestucca spill on intertidal invertebrates.

5.2.5 Fishes

There were no observations of dead fish following the Nestucca spill, although the difficulties associated with detection of dead fish (particularly salmonids) are substantial. Nearshore habitats are extremely important as juvenile rearing areas for a number of commercially-important fish species. Moreover, numerous invertebrates found in these areas are prey of rearing fish and, therefore, an important link in the marine food web. It is equally important to emphasize, however, that fish mortality has only been documented rarely following oil spills (Duval et al. 1981). There were no observations of fish mortality in vulnerable tide pool habitats following the Vanlene spill in Barkley Sound (Ages 1972 and Herlinveaux 1972, cited in Duval et al. 1981), although a few unidentified fish were reported in English Bay and several kilometres away after the Erawan spill. A small number of fish were also reported killed following the Arrow spill in Nova Scotia, although their deaths may have been the result of chemicals used during the clean-up

response rather than the oil itself (Anon 1970, cited in Duval et al. 1981). Sublethal physiological, behavioural and pathological effects have probably occurred more frequently but have not been examined during followup studies and assessment activities. Hydrocarbon uptake leading to tainting is also an area of concern related to fish-oil interactions, although this concern tends to be more of an issue with chronic releases rather than short-term event.

One of the concerns of DFO related to the Nestucca spill was the potential impacts of Bunker C in intertidal and shallow subtidal habitats, particularly in important herring spawning areas such as the shoreline of Barkley Sound. Herring adults, eggs, larvae and juveniles occupy certain nearshore habitats and are highly susceptible to oil pollution. It has been demonstrated that hydrocarbons can cause behaviourial changes in herring and may affect juvenile development. However, the potential effects of oil on "preferred" herring spawn areas and on herring food resources are not well documented. It is possible that herring will not avoid oil-contaminated areas, which could result in high mortalities of eggs, larvae and juvenile fish.

For the most part, oil sheens and slicks observed in herring spawning areas, such as between Toquart Bay and Ucluelet, by-passed the subtidal spawning substrate and stranded along the high tide lines. Extensive searching by DFO and Nuu-Chah-Nulth Tribal Council dive teams revealed only one herring spawning site where low intertidal and subtidal habitat was oiled. This was in Stuart Bay at the mouth of Ucluelet Harbour and the site required extensive clean-up. The roe herring fishery proceeded normally in Barkley Sound and fishermen attained their quotas. The location of spawning changed for the first time in many years, although it is not known if this was related to oil as such changes do occur naturally.

There are numerous salmon spawning streams, estuarine habitats and nearshore salmon rearing areas along the West Coast of Vancouver Island. Generally these areas are located along sheltered portions of the coast and were not areas directly affected by oil from the Nestucca. As a result, the

potential for impacts on salmonids appears low.

The impact of this oil spill on other fish species such as Pacific cod, rockfish and lingcod is largely unknown. Bottom-dwelling fish in the few areas where oil was expected to reach the seafloor may be affected if their habitat or prey were contaminated by oil.

5.2.6 Birds

Over the period from 8 January to 1 April, 1989, the Canadian Wildlife Service (CWS) quantified and analyzed oiled-bird mortality, examined seabird breeding colony sites and known wintering and migration areas for the presence of oil, and conducted surveys of coastal habitats in oiled areas to determine wintering waterbird concentrations (Rodway et al. 1989). All persons involved in surveillance or cleanup operations were requested to maintain records of numbers of dead birds encountered. A total of 856 birds was collected. In many cases, dead birds were delivered to either the Pacific Rim Park Warden's office or headquarters at Amphitrite Point for identification. In addition, CWS staff maintained daily records of species collected from park beaches (Florencia Bay to Schooner Cove) after 9 January to monitor changes in the species composition of dead birds over time.

(a) Bird Mortality

Mortality of birds occurs frequently as a result of oil contamination, although there are substantial differences in the sensitivity and vulnerability of different species to oil exposure. The circumstances surrounding spills such as time of year and habitats affected have also influenced the impacts of past spills on bird populations (Duval et al. 1981). Bird mortality was not reported in the four west coast spills (Vanlene, Irish Stardust, Erawan and General M.C. Meigs) reviewed by Duval et al. (1981), although relatively large bird kills have resulted from other bunker spills. Six contaminated but mobile gulls were observed following the Vanlene spill in Barkley Sound, while some unidentified birds were reported oiled after the

grounding of the Irish Stardust (Herlinveaux 1972 and Green et al. 1974, cited in Duval et al. 1981). There is very limited information available on the impact of the Erawan spill on birds, although the Center for Short-Lived Phenomena (1975, cited in Duval et al. 1981) indicated that slight damage to birds occurred. There were no reported impacts of the General M.C. Meigs spill near Cape Flattery on local bird populations.

Rodway et al. (1989) report that a total of 3568 dead birds was found on shores of the west coast of Vancouver Island between 3 January and the end of March 1989. Dead birds were found over the entire length of Vancouver Island from Sooke to Cape Scott, although most birds were recovered from beaches within Pacific Rim National Park (44 %) and the Tofino/Clayoquot Sound area (32 %). This is evident from the data presented in Table 5-1. Rodway et al. (1989) suggest that because these areas were frequently and thoroughly inspected, counts are probably close to the actual numbers of birds that washed ashore in those areas. Data available for other areas likely underestimate actual mortality. In addition, birds were not separated from oil debris during the cleanup in some areas, while other dead birds would have sank at sea before reaching the coast of Vancouver Island.

Most dead birds (77 %) were recovered within the first two weeks after oil first reached the B.C. coast (Table 5-1). Because of the advanced state of decomposition of many of these birds, they probably had contacted oil several days earlier in waters off the Washington coast rather than in coastal areas surrounding Vancouver Island (W.E. McIntyre, pers. comm.). The largest daily number of carcasses (881) were recovered on 11 January, with the majority (625) of these being collected in the Vargas Island area (Rodway et al. 1989). Birds recovered during March had obviously washed ashore much earlier, and could not be assigned specifically to any of the time periods shown in Table 5-1.

Only a portion of the birds that washed ashore on the coast of Vancouver Island were examined to determine their species. This can be attributed primarily to the advanced state of decomposition of many of the

carcasses and the remote location of many areas where birds washed ashore (where experienced ornithologists were not available to identify carcasses). Despite these constraints, Rodway et al. (1989) were able to present data on the species composition of 856 dead birds collected along the Vancouver Island coastline (Table 5-2). Thirty-one species were identified, with Common Murres (42 %) and Cassin's Auklets (32 %) being the most frequently observed casualties. Fewer numbers of scoters (6 %), gulls (4 %) and loons (3 %) were present in the sample of identified dead birds.

Only 5620 Common Murres are estimated to breed in British Columbia, the majority nesting on Triangle Island. Over 2.3 million Cassin's Auklets breed in the province. Where local populations winter in relation to the oil trajectory and dead bird locations is presently unknown.

Rodway et al. (1989) reported several additional observations and trends that resulted from their analysis of the impacts of this event:

- The number of inshore/nearshore bird species found on the Vancouver Island coast increased with time after the event. Early casualties were mainly birds contaminated with oil in offshore areas and subsequently transported into coastal areas by prevailing currents. Those species only detected 2-3 weeks after the spill probably were exposed to oil that eventually stranded on Vancouver Island beaches.

- The vast majority (94 %) of dead birds examined by CWS were completely saturated with oil, with the proportion of partially-oiled birds increasing with time after the spill. Three percent of the carcasses identified between 3 and 18 January were only partially oiled and this proportion increased to 29 % between 23 January and 3 February.

- Many of the bird carcasses recovered from beaches were partially scavenged, including those completely covered with oil. Rodway et al. (1989) report that 54 % of the bird carcasses collected between 19 January and 03 February had been scavenged to a some extent. The species observed scavenging dead birds on beaches included Bald Eagles, Common Ravens and Northwestern Crows. Similar reports of eagles feeding on oiled bird carcasses occurred in Washington (Washington Department of Ecology 1989).

TABLE 5-1: General Location and Timing of 3226 Dead Bird Observations on the West Coast of Vancouver Island, 3 January to 8 February 1989

AREA OF COAST/ TOTAL OBSERVATIONS	DATE OF OBSERVATION 3-9 Jan	10-16 Jan	17-24 Jan	25-31 Jan	1-8 Feb
Sooke to Port Renfrew Total = 12	0	12	0	0	0
Port Renfrew to Pachena Point Total = 257	20	131	106	0	0
Pachena Point to Cape Beale Total = 135	36	15	81	0	3
Barkley Sound Region Total = 165	23	47	31	53	11
Park Beaches Region Total = 1435	975	273	152	27	8
Portland Point to Sharp Point Total = 1038	64	840	123	5	6
Sharp Point to Cape Cook Total = 119	0	12	98	2	7
Cape Cook to Cape Scott Total = 65	0	1	64	0	0
TOTAL VANCOUVER IS.	1118	1331	655	87	35

TABLE 5-2: Species Composition of a Sample of Dead, Oiled Birds Collected from the West Coast of Vancouver Island from 3 January to 5 February 1989

BIRD SPECIES GROUPS	LOCATION OF OBSERVED CARCASSES					
	Park Beaches	Barkley Sound and south	Clayoquot Sound	North of Clayoquot	Unspec. Locat.	TOTAL
Loons	17	2	3	2	1	25
Grebes	8	3	-	-	1	12
Fulmars	6	1	2	-	1	10
Shearwaters	-	1	-	-	-	1
Cormorants	8	1	1	1	2	13
Scoters	45	2	3	1	4	55
Diving Ducks	8	-	-	-	-	8
Sanderlings	1	-	-	-	-	1
Gulls & Kittiwakes	22	7	-	-	5	34
Alcids	517	77	49	22	32	697
TOTALS	632	94	58	26	46	856

Rodway et al. (1989) report that delayed mortality of some partially-oiled birds may be expected. During mid January about 10 to 20 % of the live gulls in the Pachena Bay/Ucluelet area were partially oiled (Al Burger, pers. comm., cited in Rodway et al. 1989), while oiled loons, grebes and scoters were sighted frequently in the Bunsby Islands area (Jane Watson, pers. comm., cited in Rodway et al. 1989). CWS staff frequently observed extensively oiled but live birds as far south as Keeha Bay and as far north as Triangle Island.

Murres, grebes and scoters were also the primary species among the approximately 9000 birds affected by oil from the Nestucca within the state of Washington, with 80 % of the losses being Common Murres (Don Kane, pers. comm., cited in Rodway et al. 1989).

(b) Contamination of Seabird Breeding Colony Sites

Rodway et al. (1989) report that oil was encountered on seabird breeding colony islands from Seabird Rocks south of Barkley Sound on the west coast of Vancouver Island to as far north as the Moore Islands north of Bella Bella on the mainland coast. However, only the seabird colonies south of the Brooks Peninsula were contaminated with amounts of oil considered potential threats to bird populations and the oil was removed from these sites by cleanup response teams. Rodway et al. (1989) found small quantities of oil on Triangle Island and other important seabird colony sites off the northern mainland coast and removed this oil during their surveys. The colony islands considered to be most extensively contaminated with oil were the gull nesting islet at the southwest corner of the Bunsby Islands, Thorton Island, Cleland Island and Seabird Rocks. In addition, large quantities of oil stranded on the west end of the Brooks Peninsula south of Solander Island. Oil was removed from each of these areas during the cleanup response. The long-term effects of Nestucca spill on these, or other, seabird breeding colony sites has not yet been determined.

(c) Rehabilitation Efforts and Success

Only a small number of live birds were brought to rehabilitation centres in Tofino (30) and Ucluelet (3). This is because the vast majority of the birds washing ashore on Vancouver Island beaches were already dead. Nineteen of the 33 birds (58 %) cleaned were subsequently released (Ken Langelier, pers. comm., cited in Rodway et al. 1989). Staff of the Nanaimo Veterinary Hospital treated 26 of the 33 live birds brought to the rehabilitation centres.

5.2.7 Marine Mammals

During the response to the Nestucca spill, top priority was given to assessment of the presence or absence of oil in the vicinity of two sea otter colonies. Sea otters are an endangered species and, at present, there

are only two colonies in Canada. Both colonies are located on the west coast: one in the Kyuquot Sound area and a splinter colony at Bajo Reef. In addition, sea otters are known to be both highly vulnerable and sensitive to oil exposure (Baker et al. 1981; Richardson et al. 1983). The otter colonies were monitored on a regular basis by marine mammal specialists to ensure that if the animals came in contact with oil, an immediate rescue response would be initiated. Vancouver Aquarium staff were prepared to assist in any rescue operations.

Although significant amounts of oil were observed in the immediate vicinity of both otter colonies, only one oiled dead animal was collected. The dead sea otter was found on Gull Islet (Bunsby Island area) on 22 January and had oil on about 25 % of its body surface. The carcass was later autopsied and the cause of death (hypothermia and drowning) was confirmed to be related to oil. Several otters were hauled out in the Bunsby Island group and this was the first observation of this behaviour in Canadian waters. Otherwise, the behaviour (rafting, feeding, preening) and distribution of sea otters appeared normal. Observations of otters were conducted under winter conditions which allow limited accuracy compared to summer surveys; the latter are currently planned.

Extensive aerial and vessel surveys were conducted in the vicinity of sea lion, seal and sea otter colonies, particularly between Barkley Sound and the Brooks Peninsula. Some oil-contaminated seals and sea lions were reported. Peter Olesiuk (15 March 1989) summarized seal and sea lion incidents that were potentially related to the Nestucca oil spill. On 5 January, Harold Touchie and associates observed several California sea lions on Wouwer Island that were possibly oiled. Four Stellar sea lions that appeared to be oiled were observed by C. Redhead at Race Rocks (21 January). Some 200-300 California and Stellar sea lions were present on Wouwer Island when oil reached this area and photographs confirm that some of the animals were oiled. Within a few days, the sea lions on Wouwer Island had moved to an adjacent island that was not contaminated. In all cases, the animals appeared healthy and exhibited normal behaviour. Several harbour seals from a variety

of locations were reported to be oiled. For example, CWS staff observed live, oiled seals on Cleland Island (11 January) and Thornton Island (14 January), while a dead seal was reported at the north end of Long Beach by T. Curley on 12 January and another at Pachena Point by a clean-up crew two days later. A number of additional mammal-oil interactions (mostly seals and sea lions) were reported, but the sightings were either not confirmed or the cause of death was not related to oil exposure, based on examinations by veterinary pathologists. During the response to the Nestucca oil spill in coastal waters of Vancouver Island, a total of 8 seals, 18 seal lions and 2 elephant seals was reported to have come in contact with the oil.

5.3 Effects on Resource Use

5.3.1 Native Resource Use Activities

The Nuu-Chah-Nulth Tribal Council (NTC) represents 14 Indian Bands on the West Coast of Vancouver Island. The Kwakiutl District Council represents an additional two bands in the Quatsino Sound/Cape Scott area. In a recent submission to the West Coast Offshore Exploration Environmental Assessment Panel (October 1985), the NTC summarized the socio-economic importance of marine resources to their communities. These resources are harvested by Nuu-Chah-Nulth and Kwakiutl tribal communities from Ozette on the Washington coast to Cape Scott at the northwestern end of Vancouver Island. In addition to commercial fisheries, marine resources throughout the Tribal territories are utilized as traditional foods, craft materials and medicines. Areas of special importance for marine resource harvest have been included in the GIS map database prepared by ESL.

The NTC emphasizes the relative importance of marine resources to individual Native fishermen within traditional fishing territories. A household survey conducted in Kyuquot indicates that an average of one meal per day is based on seafood and that these meals are generally taken from areas that are traditional to a specific family. Although the dependence on different species would vary with resource availability, salmon is used more

frequently than shellfish and herring by Native households. Most Natives consider marine resources to be essential to the continued survival and integrity of the coastal communities (NTC 1985).

According to the NTC (1985), renewable fishery resources are the single most important contribution to the economy of the coastal communities, and in many cases, they make up the entire economic base. For example, commercial fisheries in the Kyuquot community accounts for up to 60 percent of their total employment income. The major sources of income in native fisheries are salmon and herring fishing and clam digging.

Commercial fishing provides the primary source of cash income for the Kyuquot and five other Nuu-Chah-Nulth communities. The Tribal Council suggests that even a small impact on resource harvest resulting from an oil spill could have a major impact on income of Nuu-Chah-Nulth fishermen. A five percent reduction in catch could significantly reduce the income of individual fishermen and possibly put them out of business (NTC 1985).

Although fishing generates the highest income, clam digging is also an important source of income for commercial fisheries, particularly during the winter months (October to March). Shellfish is also an important staple in the diet of Native families.

Native Indian communities in the vicinity of Pacific Rim National Park generate income from the half a million tourists that visit the area annually through a combination of marine transport, guiding and retail craft businesses. The short- and long-term impacts of the Nestucca oil spill on the local tourist industry are discussed below in Section 5.3.5.

5.3.2 Local Fisheries

As a precautionary measure, DFO closed Statistical Area 23 (Barkley Sound) on 6 January to all bivalve harvesting and Statistical Area 24 (Amphitrite Point to Estevan Point) to gooseneck barnacle and mussel

harvesting. Following extensive inspection sampling and organoleptic testing of oysters, mussels, clams, gooseneck barnacles and some other species, area 23 was re-opened to commercial oyster harvesting on 18 January and for all bivalves on 20 January. Because the shellfish beds in Mayne Bay (Area 23) were directly exposed to oil, the harvest of oyster stocks was not permitted in this area. Tainting of some species was confirmed in Area 24 and, therefore, the area remained closed for mussels and gooseneck barnacles until 25 January.

Extensive shellfish and diving surveys in Statistical Areas 25, 26 and 27 have been conducted by DFO in cooperation with the Native bands. No closures resulted from these investigations.

Production statistics for shellfish in Areas 23 to 27 are among those data published each year by DFO. These areas are usually open for commercial bivalve harvesting from November to March and closed for the remainder of the year due to the potential of contamination from paralytic shellfish poisoning (PSP).

The commercial crab fisheries in Clayoquot Sound, in Templar and Heynan Channels and off the Tofino-Ucluelet shoreline to seaward (Fisheries Statistical sub-areas 124-3, 124-1 and 24-8), were closed on 18 January due to extensive oil fouling of both crabs and trap gear, and remained closed through March. There was no evidence of oil contamination in other areas examined including Ahousat, Monk Island, Lemmens Inlet and Browning Passage.

Shrimp and prawn fisheries along the coast of Vancouver Island remain closed for routine conservation reasons, and hence no information is available for these fisheries.

Commercial hagfish fishermen in the Newcombe Channel area of Barkley Sound have experienced no problems related to the fouling of traps (DFO 1989). Similarly, there were no reports of contamination of catches and fishing gear up by personnel involved in the commercial groundfish fishery.

The Barkley Sound herring roe commercial fishery commenced in March. As a precautionary measure, several samples of herring were collected for organoleptic analysis (e.g., 21 and 22 January; 6 to 10 February) from the Barkley Sound area and offshore banks adjacent to the Sound. Results of the tests were negative and the fishery proceeded normally, except for the change in spawning area noted in Section 5.2.5.

5.3.3 Salmonid Aquaculture

Fish farms on the west coast of Vancouver Island are located in protected areas away from the exposed headlands and islands that received most of the oil following the Nestucca spill. As a result, the event appears, to date, to have had little effect on the salmon farming industry in this region. All salmon farmers in the region were contacted by telephone by the B.C. Ministry of Agriculture and Fisheries. Only four farmers (Cypress Bay in Clayoquot Sound, near Tofino at Saranac Island and near Meares Island at Mussel Rock) reported the presence of oil in or around their sea pens (R. Cox, pers. comm.). In the two latter cases, an oil sheen moved across the water and through the nets on 10 January. One of the growers (Royal Pacific Sea Farms Ltd., Meares Island at Mussel Rock) reported two oil globules adhering to a guard net, and in this case, the site manager discontinued feeding the stock until the sheen had moved out of the net area. No losses of stock were reported.

The British Columbia Salmon Farmers Association (BCSFA) was contacted in Vancouver by the authors and by DFO inspection staff. According to Diana Cooke-Dallin from BCSFA, the salmon farmers on the west coast had not reported any problems or concerns associated with the Nestucca oil spill.

5.3.4 Shellfish Aquaculture

Shellfish leases and wild stocks of bivalve shellfish are generally located in sheltered bays and along protected areas of the shoreline; conversely, most of the oil from the Nestucca affected exposed

outer coast areas. All oyster growers in the region were contacted by telephone by the B.C. Ministry of Agriculture and Fisheries during January, and both wild and cultured stocks were inspected in February. Although one incident was reported where wild shellfish beds were exposed to oil in Mayne Bay, the cultured oysters in an adjacent area, Pipestem Inlet, were not found to be contaminated. No cultured oyster stocks were reported to be contaminated as a result of this spill.

Several Barkley Sound growers reported oil on their shellfish leases. Samples were taken for organoleptic analysis and no evidence of oil or tainting was found (R. Cox, pers. comm.). Oceansport Enterprises in Cigarette Cove, Barkley Sound, reported a few small pieces of oiled debris (eelgrass, wood) floating around within the cove (R. Cox, pers. comm.).

Shellfish farmers were affected by the closure by DFO of Statistical Areas 23, 24 and 124 for shellfish harvest (B. Baden, pers. comm.). Commercial clam diggers in the Barkley Sound area had to forgo potential clam harvests from 21 tides during January due to both the shellfish closure and the possibility that the harvest could not be marketed (Pirquet 1989).

5.3.5 Tourism

The west coast of Vancouver Island was exposed to oil in varying amounts from Victoria to Cape Scott. Although a cumulative total of about 150 km of beaches and intertidal habitats was contaminated with Bunker C from the Nestucca, only a very small area (2-3 km) was heavily oiled (Class 5). Nevertheless, local people were concerned that the widespread, low-level contamination of recreational beaches may affect tourism during 1989. Potential visitors to the west coast may be concerned that their personal enjoyment will be reduced due to presence of oil on the beaches, particularly if they perceive that environmental quality, wildlife and park beach resources have deteriorated as a result of the event. If this is the case, the direct and indirect economic impact, in terms of local employment, future investment

and expansions to tourist facilities could be significant (W. McIntyre, pers. comm.).

The following reports substantiate the discontinuity of oil contamination along park and reserve shorelines. Gibsons Marine Park, Macquinna Park (Hot Springs Cove) and Baeria Rocks Ecological Reserve were not exposed to oil from at least 5 to 13 January, whereas Cleland Island Ecological Reserve and Cape Scott Park (Guise Bay) were both extensively oiled by 11 and 24 January, respectively (D. Fraser, pers. comm.).

The Pacific Rim National Park extends from Port Renfrew to Point Cox and includes the Broken Group Islands. From a tourism and recreation perspective, the park is internationally recognized as an accessible, protected, and natural coastal environment. Half a million tourists visit the park annually to view and experience a variety of unique and ecologically sensitive environments. Areas of particular concern due to their susceptibility to oil fouling and the short-term toxic effects of hydrocarbons on plants and animals are: (1) the micro-environment of tide pools; (2) sea caves and deep surge channels (may emanate an oily smell at low tide); (3) logs, rocks and bedrock at Beach Heads; (4) beaches (e.g., Barge Beach and beaches in Wickaninnish and Pachena Bays); (5) feeding areas for gray whales; and (6) breeding and moulting areas for Dungeness Crab (Wickaninnish Bay). Several of the beaches and tide pools within the area were oiled extensively on 5 January and were re-oiled after the initial stranding of Bunker C. The short-term impacts of the Nestucca spill on tourism to this area were difficult to quantify at the time of the spill because very few people visit the park during the winter months.

Long-term impacts of the spill on the rate of visitation to the park may become evident later in the year and in subsequent years. The park environment supports numerous tourist-related activities that may be adversely affected if evidence of oil contamination persists within the area. Longer-term impacts of the oil spill may be evident for the following activities: (1) water sports such as fishing, boating, diving (photography, intertidal and

sub-tidal wrecks), kayaking, surfing etc.; (2) land-based activities including camping, beachcombing, photography, hiking/backpacking, examining tidal pools etc.; (3) recreational harvests of shellfish and crustaceans; (4) visiting points of interest such as archaeological sites, whale feeding areas and geological sites including sandstone shelves and fossils in situ; and (5) ongoing research programs focusing on the inter- and subtidal life, ecological reserves, and marine mammal and raptor populations.

6.0 LITERATURE CITED

Ages, A.B. 1972. The VANLENE accident, March 1972. Marine Sciences Branch. Pacific Marine Sciences Report No. 72-4. 10 pp.

Anon. 1970. Report of the task force - operation oil (cleanup of the ARROW oil spill in Chedabucto Bay). Volume 2. Compiled at Atlantic Ocean Lab., Bedford Institute, Dartmouth, Nova Scotia. Information Canada, Ottawa. 104 pp.

Baker, J.R., A.M. Jones, T.P. Jones, and H.C. Watson. 1981. Otter Lutra lutra L. mortality and marine pollution. Biol. Conserv. 20: 311-321.

Blumer, M. and J. Sass. 1972. Indigenous and petroleum-derived hydrocarbons in a polluted sediment. Mar. Pollut. Bull. 3: 92-93.

Blumer, M., M. Ehrhard, and J.H. Jones. 1973. The environmental fate of stranded crude oil. Deep-Sea Res. 20: 239-259.

Butler, J.N., B.F. Morris, and J. Sass. 1973. Pelagic tar from Bermuda and the Sargasso Sea. Bermuda Biol. Stn. Spec. Publ. 10. 346 pp.

Centre for Short-Lived Phenomena. 1975. Event No. 8973. Record No. 23. Smithsonian Institute.

Clark, R.C., Jr. and W.D. MacLeod, Jr. 1977. Inputs, Transport Mechanisms, and Observed Concentrations of Petroleum in the Marine Environment. Chap. 2 In: Malins, D.C. (ed.) Effects of Petroleum on Arctic and Subarctic Marine Environments and Organisms. Academic Press Inc., New York. pp. 91-224.

Clark, R.C., Jr., J.S. Finley, B.G. Patten, and E.E. DeNike. 1975. Long-term chemical and biological effects of a persistent oil spill following the grounding of the General M.C. Meigs. In: Proceedings of 1975 Conference on Prevention and Control of Oil Pollution. American Petroleum Institute, Washington. pp. 479-487.

Clark, R.C., Jr., B.G. Patten, and E.E. DeNike. 1978. Observations of a cold-water intertidal community after 5 years of a low-level, persistent oil spill from the GENERAL M.C. MEIGS. J. Fish. Res. Board Can. 35: 754-765.

Conomos, T.J. 1975. Movement of spilled oil as predicted by estuarine nontidal drift. Limnol. Oceanogr. 20: 159-173.

Conover, R.J. 1971. Some relations between zooplankton and Bunker C oil in Chedabucto Bay following the wreck of the Tanker Arrow. J. Fish. Res. Board Can. 28: 1327-1330.

Cross, W.E., D.H. Thomson, and A.R. Maltby. 1983. Macrobenthos - 1982 study results. (BIOS) Baffin Island Oil Spill Working Report 82-3. 135 pp.

Dennis, J.V. 1959. Oil pollution survey of the United States Atlantic Coast with special reference to southeast Florida Coast conditions. Am. Petrol. Inst. Publ. 4054. 81 pp.

Duval, W.S. (ed.). 1985. A review of the biological fate and effects of oil in cold marine environments. Unpubl. Rep. by ESL Environmental Sciences Limited, S.L. Ross Environmental Research Limited and Arctic Laboratories Ltd. for Environment Canada, Environmental Protection Service, Edmonton. 242 pp.

Duval, W.S., L.C. Martin, and R.P. Fink. 1981. A prospectus on the biological effects of oil spills in marine environments. Unpubl. Rep. by ESL Environmental Sciences Limited for Dome Petroleum Limited, Calgary, Alberta. 92 pp + appendices.

Fingas, M. 1989. Report on the "sunken" oil found during the Nestucca incident. Unpubl. Rep.by Environment Canada, Environmental Emergencies Technology Division, Ottawa.

Fingas, M.F., W.S. Duval, and G.B. Stevenson. 1978. The Basics of Oil Spill Cleanup, with particular reference to southern Canada. Environment Canada, Environmental Protection Service, Ottawa. 155 pp.

Green, D.R., C. Bawden, W.J. Cretney and C.S. Wong. 1974. The Alert Bay oil spill: a one year study of the recovery of a contaminated bay. Unpubl. Manusc. Marine Sciences Directorate, Pacific Region, Pacific Marine Science Report 74-9. 42 pp.

Herlinveaux, R.H. 1972. Preliminary report on the oil spill from the grounded freighter VANLENE. Environment Canada, Marine Sciences Directorate, Pacific Region. Pacific Marine Science Report No. 72-11. 11 pp.

Kolpack, R.L., J.S. Mattson, H.B. Mark, Jr., and T-C. Yu. 1971. Hydrocarbon content of Santa Barbara Channel sediments. In: Biological and Oceanographical Survey of the Santa Barbara Oil Spill, Vol. II. Allan Hancock Foundation, University of Southern California, Los Angeles. pp. 276-295.

MacKay, D. 1984. The behaviour and fate of oil in cold climates. Unpubl. Rep. for Environment Canada, Environmental Protection Service, Ottawa.

National Academy of Sciences. 1975. Petroleum in the Marine Environment, Washington, D.C. 107 pp.

Nelson-Smith, A. 1973. Oil Pollution and Marine Ecology. Plenum Press, New York. 260 pp.

Nuu-chah-nulth Tribal Council. 1985. Presentation to the West Coast offshore exploration environmental assessment panel. October, 1985. 57 pp.

Owens, E.H.. 1977. Coastal environments of Canada: the impact and cleanup of oil spills. Fisheries and Environment Canada, Environmental Protection Service, Environmental Impact Control Directorate, Economic and Technical Review Rept. EPS-3-EC-77-13. 413 pp.

Pirquet, K.T. 1989. West Coast oil spill too close for comfort. Canadian Aquaculture. Vol 5(2). pp. 55-56.

Quayle, D.B. 1974. The VANLENE oil spill. Fish. Res. Board Can. Manuscript Rep. Ser. No. 1289. 21 pp.

Rashid, M.A. 1974. Degradation of Bunker C oil under different coastal environments in Chedabucto Bay, Nova Scotia. Estuarine Coastal Mar. Sci. 2: 137-144.

Richardson, W.J., C.R. Greene, J.P. Hickie, and R.A. Davis. 1983. Effects of offshore petroleum operations on cold water marine mammals, a literature review. Prep. by LGL Limited for Environmental Affairs Department, American Petroleum Institute, Washington, D.C. API Rep. No. 4370. 248 pp.

Rodway, M.S., M.J.F. Lemon, J-P Savard and R. McKelvey. 1989. Nestucca oil spill: impact assessment on avian populations and habitat. Draft unpubl. tech. rept., Canadian Wildlife Service. 8 pp + appendices.

Shaw, D.G., A.J. Paul, L.M. Cheek, and H.M. Feder. 1976. Macoma balthica: an indicator of oil pollution. Mar. Pollut. Bull. 7: 29-31.

Sleeter, T.D. and J.N. Butler. 1982. Petroleum hydrocarbons in zooplankton fecal pellets from the Sargasso Sea. Mar. Pollut. Bull. 13: 54-56.

Spooner, M. 1969. Some ecological effects of marine oil pollution. In: Proceedings of 1969 Joint Conference on Prevention and Control of Oil Spills. American Petroleum Institute, Washington, D.C. pp. 313-316.

Thomas, M.L.H. 1973. Effects of Bunker C on intertidal and lagoonal biota in Chedabucto Bay, Nova Scotia. J. Fish. Res. Board Can. 30: 83-90.

Thomson, R.E. 1981. Oceanography of the British Columbia coast. Canadian Special Publ. of Fisheries and Aquatic Sci. 56. Department of Fisheries and Oceans. 291 pp.

Vandermeulen, J.H. and D.C. Gordon, Jr. 1976. Re-entry of 5-year-old stranded bunker C fuel oil from a low-energy beach into the water, sediments, and biota of Chedabucto Bay, Nova Scotia. J. Fish. Res. Board Can. 33: 2002-2010.

PERSONAL COMMUNICATIONS

Baden, B.	Aquaculture Association of B.C.
Cook-Dallin, D.	British Columbia Salmon Farmers Association
Cox, R.	Ministry of Agriculture and Fisheries
Englan, R.	Environment Canada
Fraser, D.	Ministry of Parks
Hebron, K.	Environment Canada
Kay, B.	Environment Canada
Langford, R.W.	Ministry of Environment
McAllister, C.	Department of Fisheries and Oceans
McIntyre, W.E.	Parks Canada
Olesiuk, P.	Department of Fisheries and Oceans
Palm, R.	Shark Salvage
Wilson, B.	Environment Canada

Appendix A: Stranded Oil Classification System

SHORELINE CONTAMINATION

CLASS 1

- no visible oil on surface of rock or beach
- no visible oil in subsurface sediments
- no visible oil in or on logs

CLASS 2

- sheen ("rainbow oil") on surface of rock or beach
- no visible black oil on rock or beach
- thin (less than 1 inch or 2 centimters) cover of oil on logs or on rocks

CLASS 3

- sheen ("rainbow oil") on surface AND brown or black oil
- size of brown or black oil is dime/nickel size or less with occasional hand size blobs

CLASS 4

- surface oil cover on rocks and/or beach is thick (more than 1 inch)
- size of blobs is plate or cow-patty and larger
- logs have blobs or oil cover greater than 1 inch thick

CLASS 5

continuous oil cover, not blobs, greater than 3 inches thick

OIL COVER ON SHORE

LIGHT

- 5 to 10 % of the shore covered with sheen ("rainbow oil")
- brown/black blobs no greater than nickel/dime size
- no more than 10 blobs per square meter

MODERATE

- brown/black oil blobs of plate or cow-patty size
- more than 1 blob per square meter
- greater than 10 metes of shore contaminated

HEAVY

- brown/black blobs of plate size or larger over more than 10 meters of shore but not continuous oil cover

COMPLETE CONTAMINATION

- brown/black oil on surface covers more tnan 25% of the shore
- more than 25 meters length of shore contaminated

Appendix B: Dive Survey Reports

REPORT BY RANDOLPH KASHINO, ESL 11/01/89

DIVE SURVEYS NEAR TOFINO

0900H Meet with Rod Palm and mobilze for diving.

0940H Arrive site in Templar channel off north side of Wickaninnish Island about 500m. Tie up to Crab trap float with number 23668. This belongs to F.V."Vargas Isle"-owner Peter White.

0942-1027H Dive on site.
Depth: 4.5 meters.
Visibility: 3 to 4 meters.
Water Temperature: 7.4 degrees C.
Bottom: Sand with sand ripples with wavelength of 10cm and depth of 2 to 4 cm.

Observations: Oil was found stuck to side of crab trap with eelgrass. Small spheres of oil about 2 cm in diameter were seen on the bottom. They would move about the bottom with water current surges caused by wave swell. They were observed to be negatively buoyant at this water depth (4.5m) and when tested fell to the bottom at 5 cm/s. A floating sphere of oil about 5mm in diameter was seen being carried along with the current. The eelgrass on the bottom had oil stuck to bases. Amongst the eelgrass Olive Shell Snails were common. Sea Pens (Ptilosarcus gurneyi) were common in this area but did not seem to have been affected. The same is true of Burried Tealia anemonaes (Tealia coriacea). Empty shells of Horse clams,Cockles and Geoduck were also seen in the area. No Dungeness Crab were seen. Photographs were taken of bottom and oil.

1045H Enroute to Ahous Bay in the La Croix Rocks Group near Moser Pt sea foam with oil was observed heaped up 20cm like soap suds.

1101H Arrive Ahous Bay (Open Bay) and tie up to crab float in middle of bay about 700m offshore of rocky point.

1117-1131H Dive on site.
Depth: 11m.
Visibility: 2 to 2.5m.
Water Temperature: 6.8 degrees C.
Bottom: Sand with sand ripples with wavelength of 4 cm.

Observations: No oil was sited on bottom. Clumps of empty polychaete worm tubes were seen and no oil was found adhering to these. Also observed in area were Olive Shell Snails, Hermit Crabs which used empty Olive Shells, juvenile flounder, and Pacific Spiny Lumpsucker. Photographs were taken of bottom.

1150H Arrive Dive site in the La Croix Group Rocks halfway between Ahous Pt. and Moser Pt. Sea foam with streaks of oil covers area.

1157-1226H. Dive on site.
Depth: 2m to 8m.
Visibility: 5 to 7m.
Water Temperature: 7.5 degrees C.
Bottom: Rock from surface to 4m then becoming 10 to 20cm cobble with patches of broken shell sand.

Observations: No oil was observed on bottom. Sea Urchins (Strongylocentrotus franciscanus) was observed in commercial abundance of 15 to 20 per square meter. Abalone (Haliotis kamtdchatkana) was also observed in commercial abundance of 1 to 5 per square meter. Rock Scallops (Hinnites multirugosa)were also observed.The rock and cobble was covered with encrusting red algae (Lithothamnia sp.) except for cobble which was active and had been moved by waves. Kelp Greenlings (Hexagrammos decagrammus) were observed in the area. Other marine life seen in the area was typical of an exposed coast rocky bottom. White cap limpets, Calliostoma snails, California mussels, Horse clams, Orange Cup Coral,Anthopluera and Tealia anemonaes were also observed at this site. Photographs were taken of bottom.

1245H Return to Tofino for Lunch and warmup.

1430H Arrive Dive site at Rassier Pt.,Vargas Island.

1447-1457H Dive on site.
Depth: 3 to 26 meters.
Visibility: 5m.
Bottom: Rock becoming rock rubble to a depth of 7m. From 7m to 26m the bottom was mud and broken shell covered extensively with eelgrass debris.
Observations: No oil was seen. The dive site is typical of a protected rocky shore. Geoduck shells were observed in abundance to indicate that the area has geoducks in commercial abundace. Dungeness and Rock Crab shell were also seen. Photographs were taken of bottom.

1515H Arrive Dive site at Kelp bed on north west corner of Wickaninnish Island. This site was chosen because Rod Palm has observed that this area usually collects a lot of debris on the bottom.

1520-1534H Dive on site.
Depth: 6 to 9 meters.
Visibility: 3 to 5m.
Bottom: Rock and boulder.

Observations: The area is a kelp bed of Bull Kelp (Nereocystis luetkeana). Sea Cucumbers (Parastichopus californianus) are common in the area. At a depth of 26 feet (7.9m) a 2cm sphere of oil was observed to be neutrally buoyant neither sinking nor floating. This indicates that the salinity and temperature at this depth has caused a water density that allows the oil to be nueutrally buoyant. Debris at 9m in this area had no oil on it. Photographs were taken of bottom in kelp bed.

1600H Return to Tofino.

1730H Return to Ucluelet.

shark salvage

P.O. BOX 213
TOFINO, B.C.
CANADA, V0R 2Z0

Report on sea bottom contamination in Clayoquot Sd.-Jan.7/89

On site were diver Rod Palm, tender Gil Palm and observer from Greenpeace Sylvaine Zimmerman on vessel "Wreck Checker".

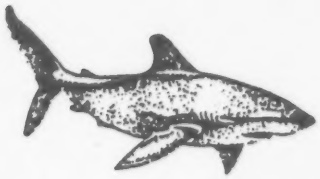
Following up on report of crab fouling called by crab fisherman Peter White, we made our first dive about 100m. of the north shore of Wickaninnish I. at a depth of about 4m. at "0" tide. On descending, the oil was not apparent until I got right on the bottom where globs up to 15cm. and globules of about 1.5cm. diameter were continuously in view throughout a 100m. lineal swim. Also observed were oil patches of about 30cm. diameter scattered about the area. No sheen was evident on any of these materials. The colour of the contaminates appeared as a very dark brown.

The next area checked was Ahous Bay. Started the next swim just outside the surf line (about 1m.) at "0" tide and swam out more or less perpendicular to the beach for about 200m. to a depth of about 30m.. The only sighting on this swim was a one meter by 20cm. diameter mass with the consistency of warm tar; may not be related to the spill. Predominant life forms in the area were olive shells, sand dollars and dunginess crabs, close examination showed no visible signs of contamination.

The last dive was started at what is locally refered to as Medalion Beach (on the exposed south side of Vargas I.) and proceeded in an easterly direction for about 1.3km.. This surveyed area varried in depthes of 2 to 12m. over sand and rocky bottoms. No physical evidence of fouling was found.

I feel the oil patches are quickly pulverized on the surf swept rocky shores as opposed to being set down on a flat beach.

Report done by Rod Palm



shark salvage

P.O. BOX 213
TOFINO, B.C.
CANADA, V0R 2Z0

Report on sea bottom contamination in Clayoquot Sd.-Jan.11/89

On site were divers Randy Kashino and Rod Palm with Gil Palm as tender on the vessel "Wreck Checker".

The first dive was made about 100m. off the north shore of Wickaninnish I. at a depth of about 4m. at "0" tide. On ariving at the bottom it was very soon apparent that the contamination was not near as bad as it was on jan.7th. We found occasional globules on the sand, then while touring around found some clumps of rooted eel grass with globules nestled in at thier bases and thier leaves matted together with the stuff. We closely inspected about 100m. of the bottom in a roughly westerly direction.

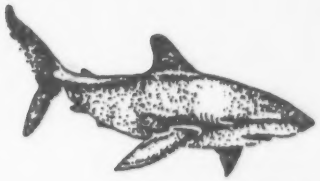
The next stop was Ahous Bay where another 100m. of bottom (sand) was looked at in a depth of about 10m. at "0" tide. Nothing was found but the bottom was considerably stired up by the ground swell.

On the La Croix reefs where we dove in an area that is a commercially active site for sea cucumber, sea urchin and abalone; these species were closely looked at and showed no visible evidence of fouling. The are looked at was about 200 square meters in depths from 2 to 7m..

Broke for lunch then went to Rassier Pt. where we went in on the west and worked our way down and around the point to the deeper basin (25m.) where we looked very closely at the bottom as we drifted with the tide for about 50m.. Nothing out of the ordinary was observed.

Some years ago I found a dead water area near the N.E. corner of Wickaninnish I. where a pocket of uprooted kelp would sit. We inspected this area thoroughly but found it visibly clean except for droves of polychaete worm casings. During the 50m. swim to this location, Randy spoted a globule of oil that apeared to be suspended in the water column about 8m.. We watched this globule for about 2 minutes without observing any change in depth.

Report done by Rod Palm



shark salvage

P.O. BOX 213
TOFINO, B.C.
CANADA, V0R 2Z0

Report on sea surface contamination,Clayoquot Sd.-Jan.19/89

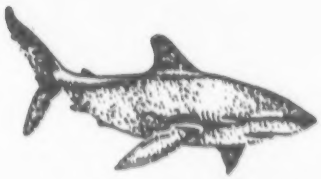
On site were Johnny Tom and friend on "Super Stud" and Rod and Pearl Palm on "Wreck Checker".

We got a report from Johnny Tom about 14:00 that a boat from Ahousat observed an oil slick in the vicinity of Elbow Bank. Met with Johnny in Father Charles Channel where the ebbing tide had moved the slick. On close observation it appeared that particles of oil were floating up to the surface. You could see a sheen develop in a clean patch of water. This sheen was spread very thinly over about 30,000 square meters. Would liked to have checked this out under the surface but by the time I went back for my gear, the slick would have been gonewith the tide out past Wilf Rks.

Did a close inspection of the sea surface along the shore from Mud Bay to MacIntosh Bay without sighting any further slicks.

Landed at beach on west side of Rassier Pt., found only two handful sized clumps matted with eel grass and an apple section.

Report done by Rod Palm



shark salvage

P.O. BOX 213
TOFINO, B.C.
CANADA, V0R 2Z0
ph. 725-3958

Report on sea bottom inspection off Long Beach Jan 22/89

On site were diver Rod Palm, Tender Mike Charron and boat operator Gil Palm.

Have been waiting a week for the swell to go down. It seems that 2m. is the highest ground swell that can be delt with otherwise the bottom is too stirred up to see anything. Swell heigth on this day was 1.99 to 2.68m..

Location of this dive was 1.9 nautical miles out on a bearing of 70 degrees from the Wickaninnish Inn. Started the swim at a depth of 78 feet then swam on a course of 70 degrees for a distance of 150m. where the depth was 75 feet. Datum of tide was about 12 feet.

We tied up to a crab float that was oiled. Found no fouling on the line as I descended and the top ring of the trap itself was clean; was unable to pull the trap out of the sand to check the bottom ring. Found no visible evidence of oil on the sand.

Little life was seen, Olive snails and something larger that swam by unidentified. There were abundant tubes (from the worm Pista pacifica?) but could not find any that were alive. Tried to dig one of the tubes out for a specimen but at about 20cm. down the sand gives way to large smooth gravel that was too dificult to dig without a tool.

It is worth noting that even at this depth there was considerable motion on the bottom making the dragging of a float line impractical.

Saw no Common Murres during all our running this day.

Report done by Rod Palm

shark salvage

P.O. BOX 213
TOFINO, B.C.
CANADA, V0R 2Z0
April 15/89

Report on seafloor inspection in Clayoquot Sd., April 12/89

On site were divers Randy Kashino and Rod Palm with Finn Mclorie as tender on the vessel "Wreck Checker".

The first dive was made about 100m. off the beach at Ahous Bay in 10m. of water with 2m. of visibility. The sand bottom appeared uncontaminated and in good health. Two species of polychaete worms were abundant. One species was about 5mm. in diameter with the tube having a flattened appearance, living in dense clusters about 25cm. across, while the other species was about 15mm. in diameter and scattered over the bottom at about 1m. intervals. Additional life noted in abundance were various species of hermit crabs and gastropods.

The next dive was made on the lee side of La Croix Rf. This is a typical exposed reef with its abundant representation of submarine phylum. This is a commercial sea urchin and sea cucumber harvesting area. No contamination of any sort was observed. Depth varied from 2 to 10m. with visibility of about 7m..

75m. off the north shore of Wickaninnish I. in about 5m. of water with 3m. visibility, the bottom appeared in good health and uncontaminated. Particular attention was given to the bases of the eel grass clusters, these were visually scrutinized and probed by hand for any traces of oil; nothing was found. A commercial abundance of horse clams were noted. This sand bottom appeared in good health and uncontaminated.

The last dive of the day was made from intertidal to 20m. of water with 2m. of visibility on a sand bottom with assorted rock outcropings. This area also appeared in good health and uncontaminated. A commercial abundance of geoducks were noted.

Report done by Rod Palm.

Appendix C: Environment Canada Analysis of Sinking Ability of *Nestucca* Oil

REPORT ON THE "SUNKEN" OIL FOUND DURING THE NESTUCCA INCIDENT

Background

Divers engaged by Environment Canada found some neutrally-buoyant oil in the Clayoquot Sound region. Dives were conducted in the Templar Channel and Father Charles channel on January 7 and 9. On both occasions, neutrally-buoyant oil was found. One location had oil floating at the 26-foot level and the other at 15 feet.

Oil was present in three forms;

1. marble size of about 2 cm diameter,
2. oblong blobs of about 7 or 8 cm, and
3. flat pancakes of 20 cm size.

The marble size particles were the most frequent and the other types were in fact rare. It should be stressed that very little oil was in fact seen during these dives. The volumes of oil involved would be very small, even if such particles were distributed over other areas of the west coast.

The diver performed two tests on the oil. The first was to take several of the marble-size particles and measure their drop rate to the 15-foot mark where they were originally located. This rate was measured to be 5 cm/sec. and was consistent among particles. Additionally, some of the oil was put on vegetation and its adhesiveness noted. The oil did not stick to the Kelp, but adhered to Eel grass.

Sample Analysis

Samples of neutrally buoyant oil were sent to RRETC for density analysis after having been split for identification analysis by C&P regional labs. When the samples arrived in late January, the neutrally buoyant oil had separated into a sunken blob and a much larger floating blob. The seawater was still clean and could also be analyzed for density. It was decided not to combine the two oil portions because adhesion to the lid and the bottom would not allow for complete mass calculation or transfer.

The results of the density analysis appears in the attached tables and graphs. The sunken material was much heavier than water and the floating oil. The graphs illustrate this. The top line is the sunken blob and the bottom line the floating oil. A theoretical 1/5 mixture of the heavy oil with the lighter one is neutrally buoyant and its density appears on the graph with the two water density lines. The lines on this graph are fit with "RS1" and show a correlation coefficient of at least 0.97.

The heavy blob was examined in detail and found to consist largely of small angular gravel, such as that derived from a beach. The oil extracted from the blob had a similar density to that of the floating oil. The beach material was definitely the source of the higher density.

Conclusions

The neutrally-buoyant oil found during the dives was rendered such by the incorporation of beach material. This material was course (1 to 3 mm) and angular. The oil adhesion is temporary and resurfacing of some oil material would occur. The remaining oil would sink. Because of the small numbers of such oil blobs noticed during the dives, it is highly unlikely that these phenomena played a significant role in the Nestucca spill.

Merv Fingas, March 3,1989

RESULTS OF THE DENSITY ANALYSIS SAMPLES FROM THE NESTUCCA SPILL

SEAWATER SAMPLES — **SAMPLE 1**

TEMP CELCIUS	DENSITY RUN 1	RUN 2	AVERAGE
0	1.023	1.0232	1.0231
5	1.0229	1.023	1.02295
10	1.0219	1.0219	1.0219
15	1.021	1.0211	1.02105
15.6	1.0208	1.0208	1.0208
20	1.0199	1.02	1.01995
25	1.0181	1.0181	1.0181
30	1.0169	1.0171	1.017

SEAWATER SAMPLES — **SAMPLE 2**

TEMP CELCIUS	DENSITY RUN 1	RUN 2	AVERAGE
0	1.0232	1.0235	1.02335
5	1.0228	1.023	1.0229
10	1.0218	1.0223	1.02205
15	1.0212	1.0213	1.02125
15.6	1.021	1.0211	1.02105
20	1.0201	1.0203	1.0202
25	1.0184	1.0184	1.0184
30	1.0172	1.0173	1.01725

FLOATING OIL

TEMP CELCIUS	DENSITY RUN 1	RUN 2	AVERAGE
0	1.0181	1.0181	1.0181
5	1.0187	1.0185	1.0186
10	1.0172	1.017	1.0171
15	1.0154	1.0149	1.01515
15.6	1.0149	1.0145	1.0147
20	1.0129	1.0125	1.0127
25	1.0098	1.0094	1.0096
30	1.0077	1.007	1.00735

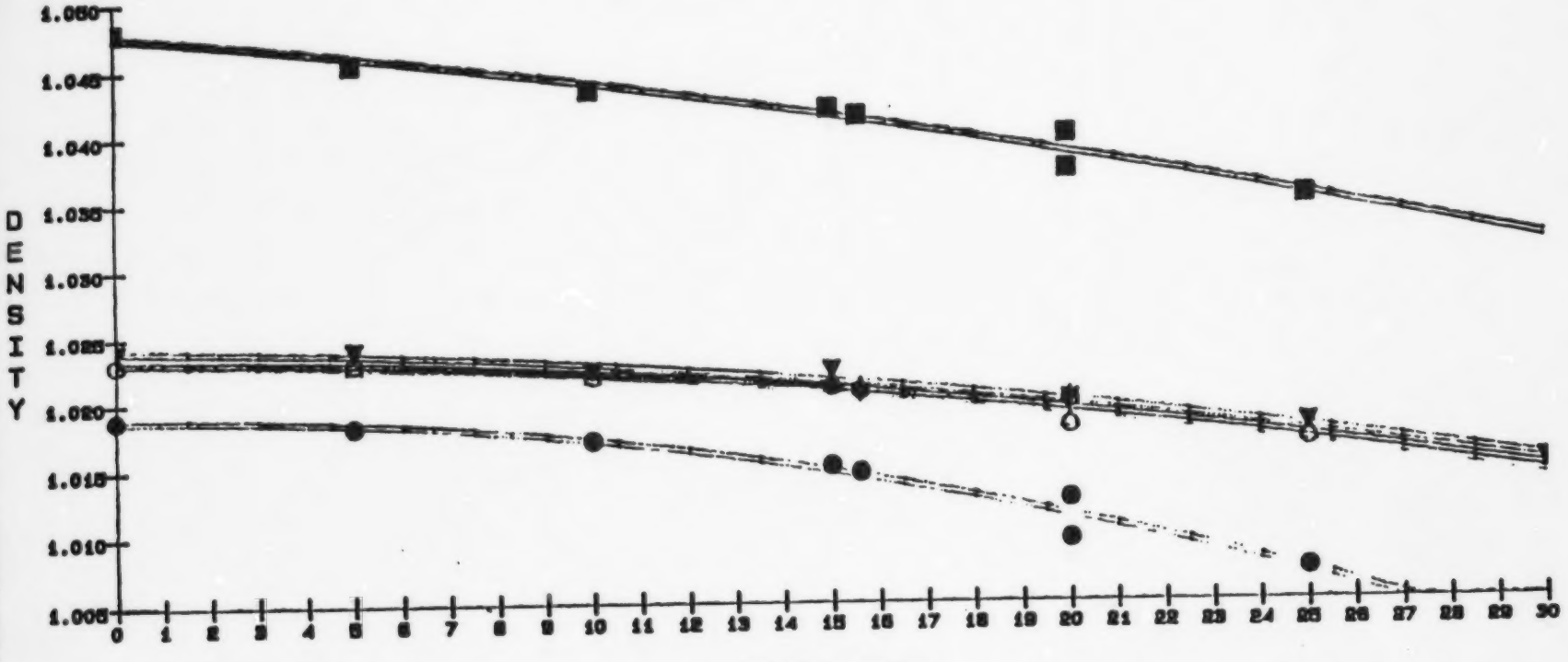
SUBMERGED OIL

TEMP CELCIUS	DENSITY RUN 1	RUN 2	RUN 3	AVERAGE
0	1.0448	1.0448	1.0544	1.048
5	1.0447	1.0447	1.0472	1.0455
10	1.0425	1.043	1.045	1.0435
15	1.0406	1.042	1.0433	1.042
15.6	1.0402	1.0415	1.0428	1.0415
20	1.0382	1.0407	1.0411	1.04
25	1.0354	1.0383	1.0384	1.0374
30	1.0329	1.0366	1.0364	1.0353

ESTIMATED NEUTRALLY BOUYANT OIL

TEMP	DENSITY
0	1.02408
5	1.02398
10	1.02238
15	1.02052
15.6	1.02006
20	1.01816
25	1.01516
30	1.01294

DENSITY OF NESTUCCA SAMPLES

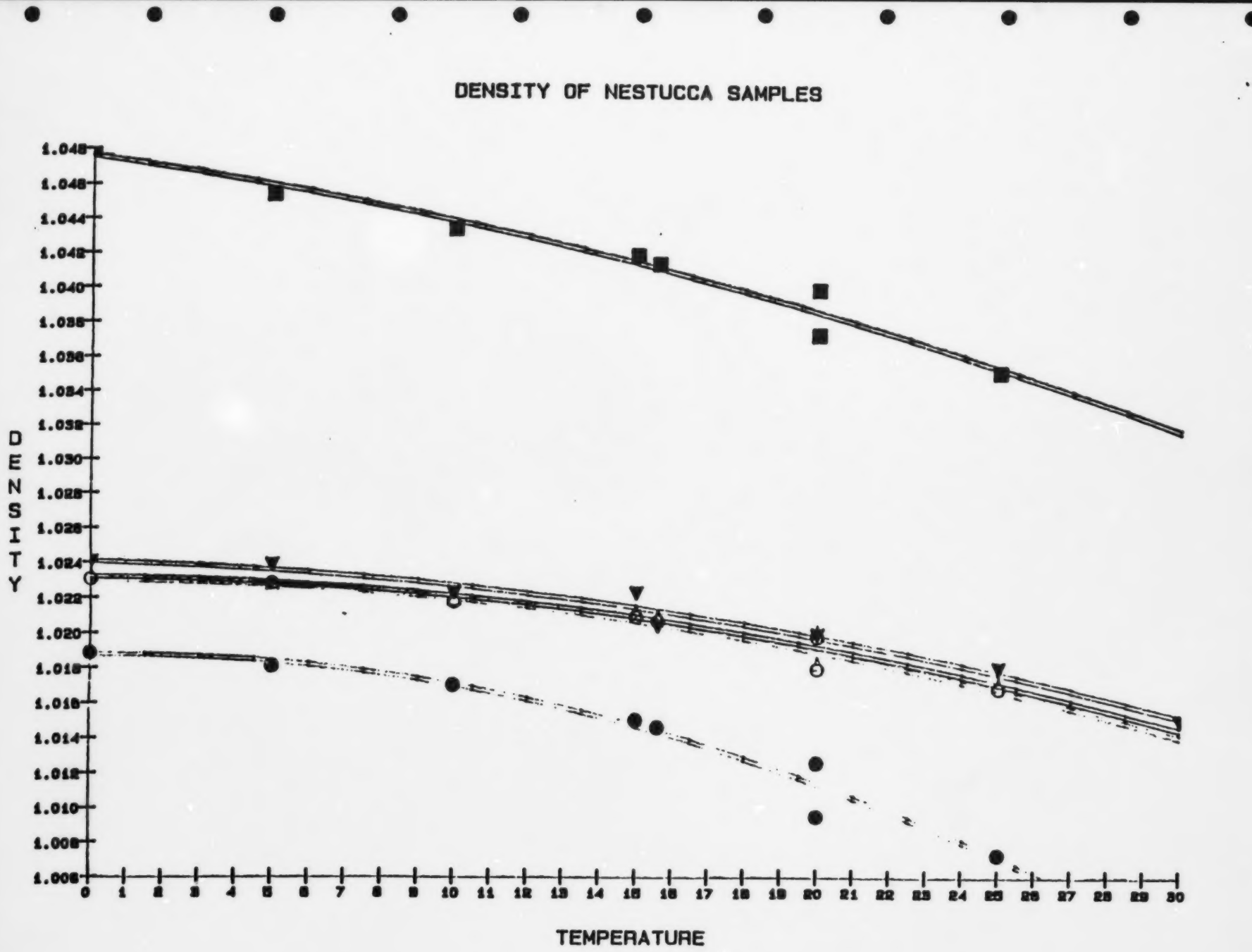


○ WATER #1
△ WATER #2
● FLOATING OIL
■ SUBMERGED OIL

-9.711996e-06*X**2 -4.815852e-06*X +1.023123
-9.277524e-06*X**2 -8.783247e-06*X +1.023268
-1.978978e-05*X**2 +2.933628e-05*X +1.018801
-7.741073e-06*X**2 -2.923699e-04*X +1.047645

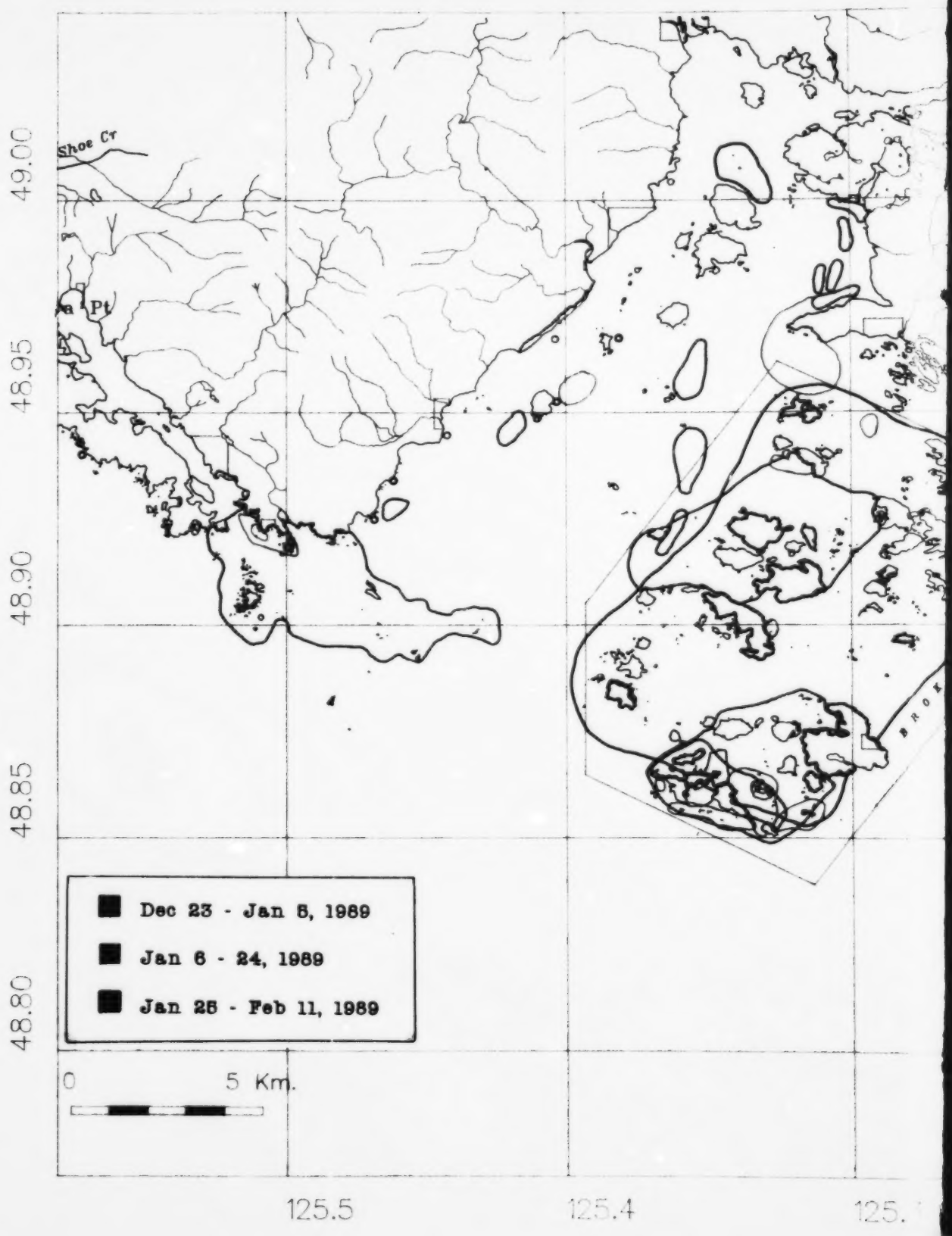
▼ ESTIMATED NEUTRALLY BOUYANT OIL

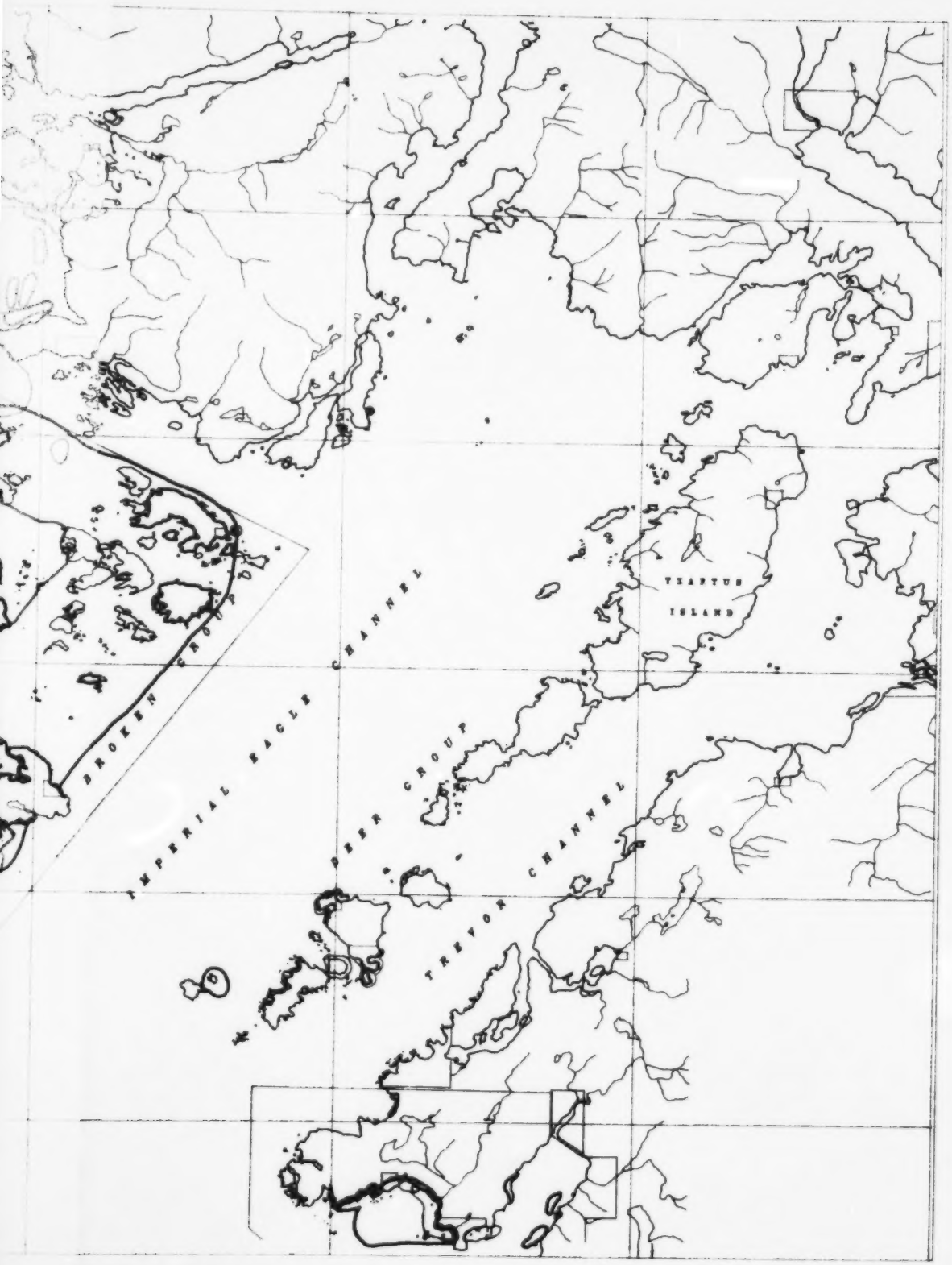
-8.161353e-06*X**2 -4.676952e-05*X +1.024114


DENSITY OF NESTUCCA SAMPLES
DENSITY
TEMPERATURE

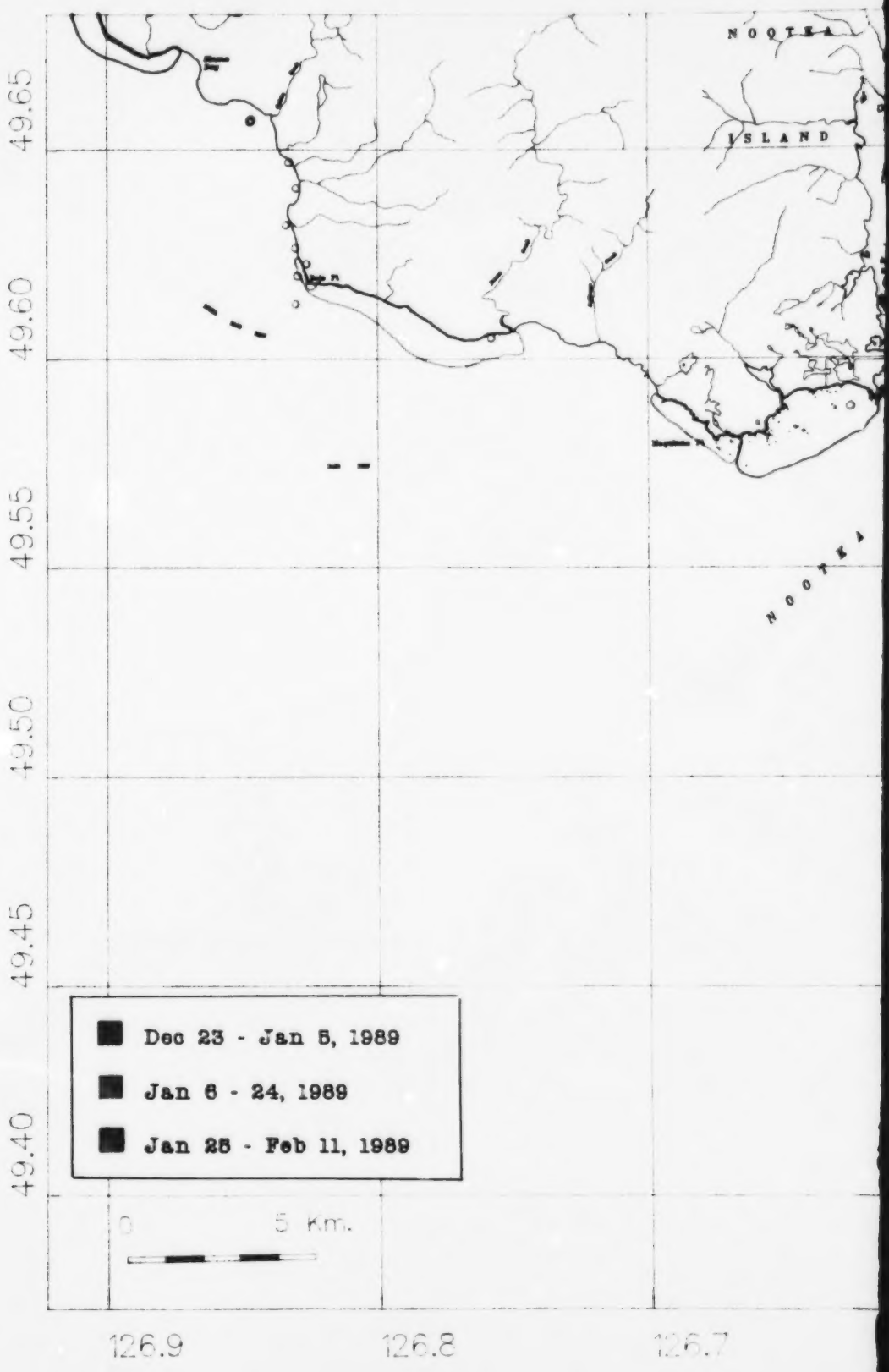
Appendix D: Representative Maps from Available Map Folio

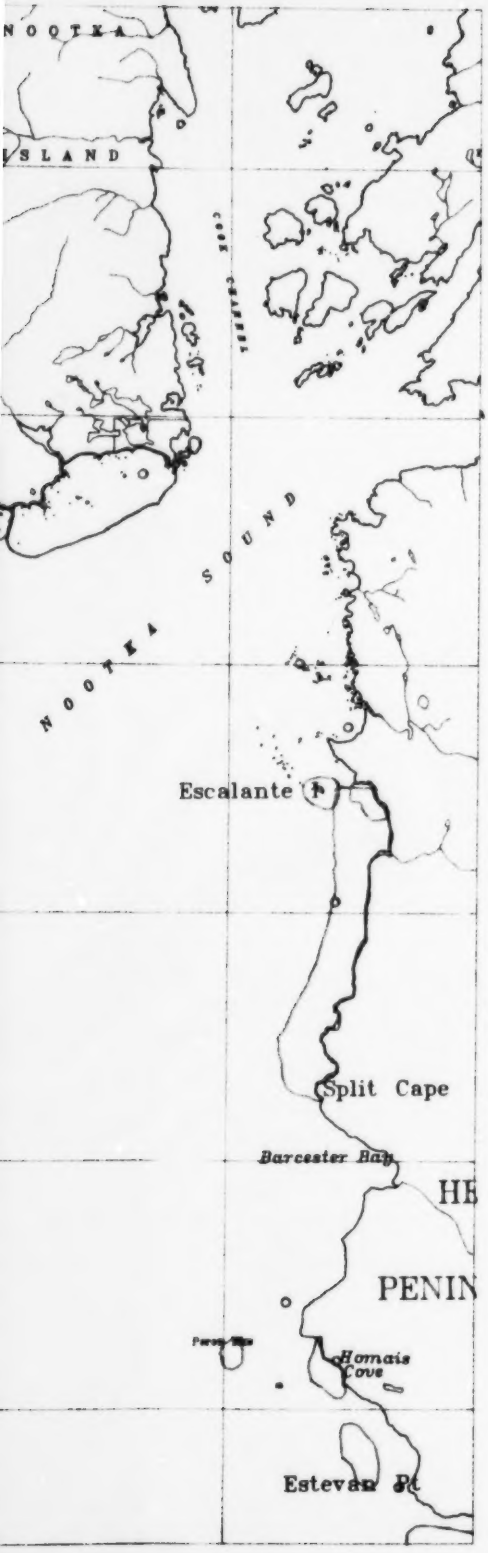
Barkley Sound Oil Time Series



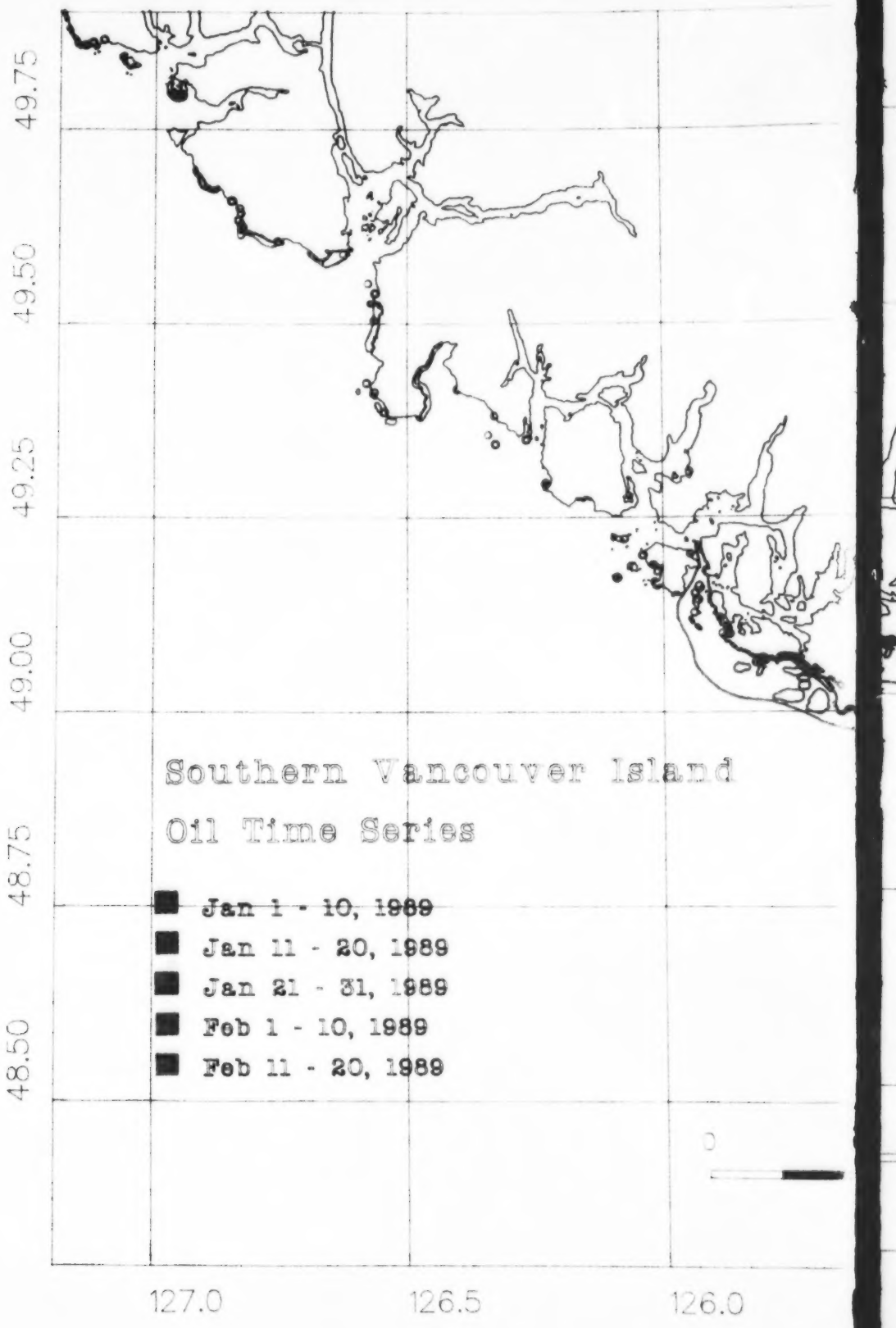

TSARTUS
ISLAND
IMPERIAL EAGLE CHANNEL
BROKEN GROUP
PEER GROUP
TREVOR CHANNEL
125.3
125.2
125.1
125.0

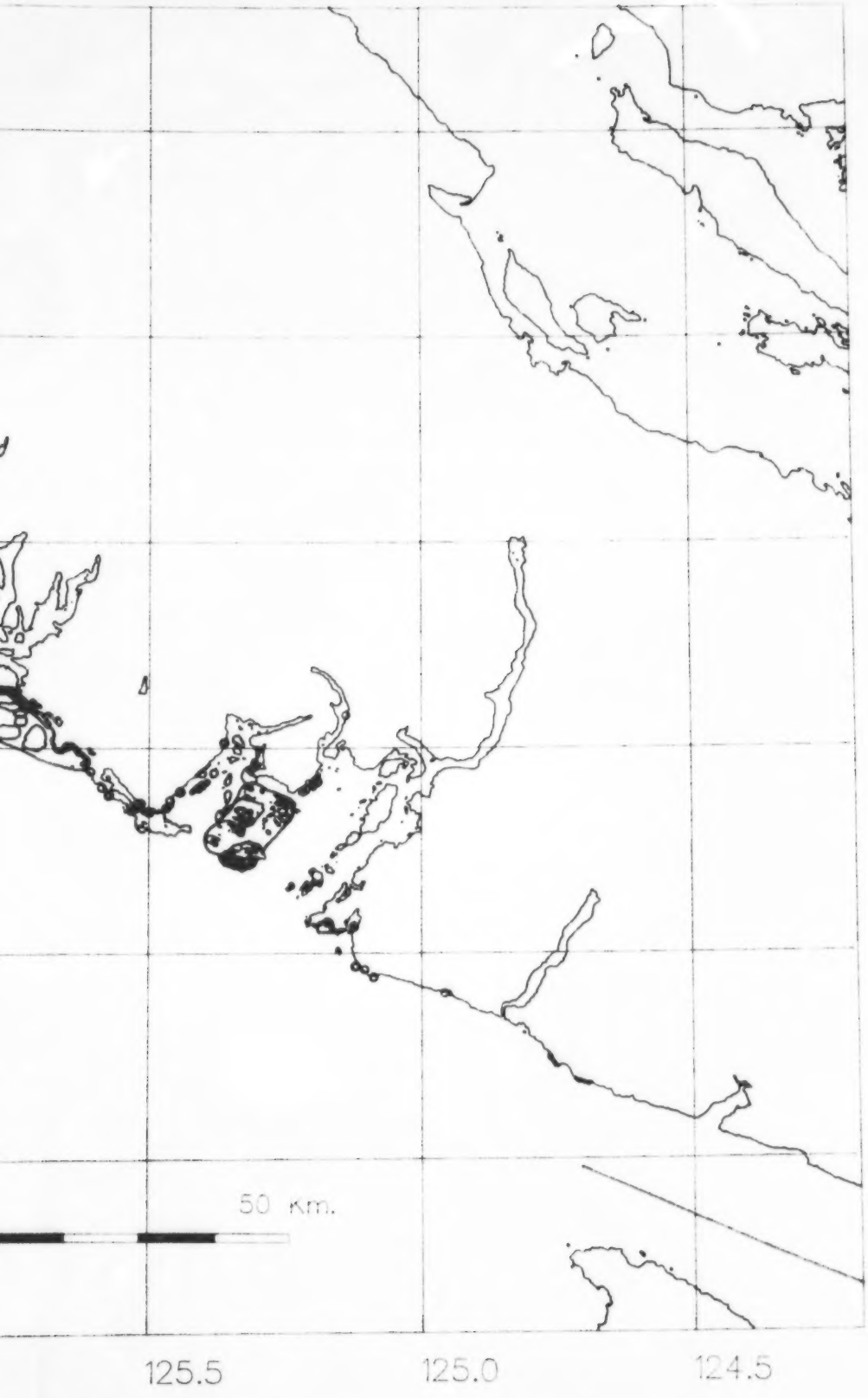
Nootka Sound Oil Time Series

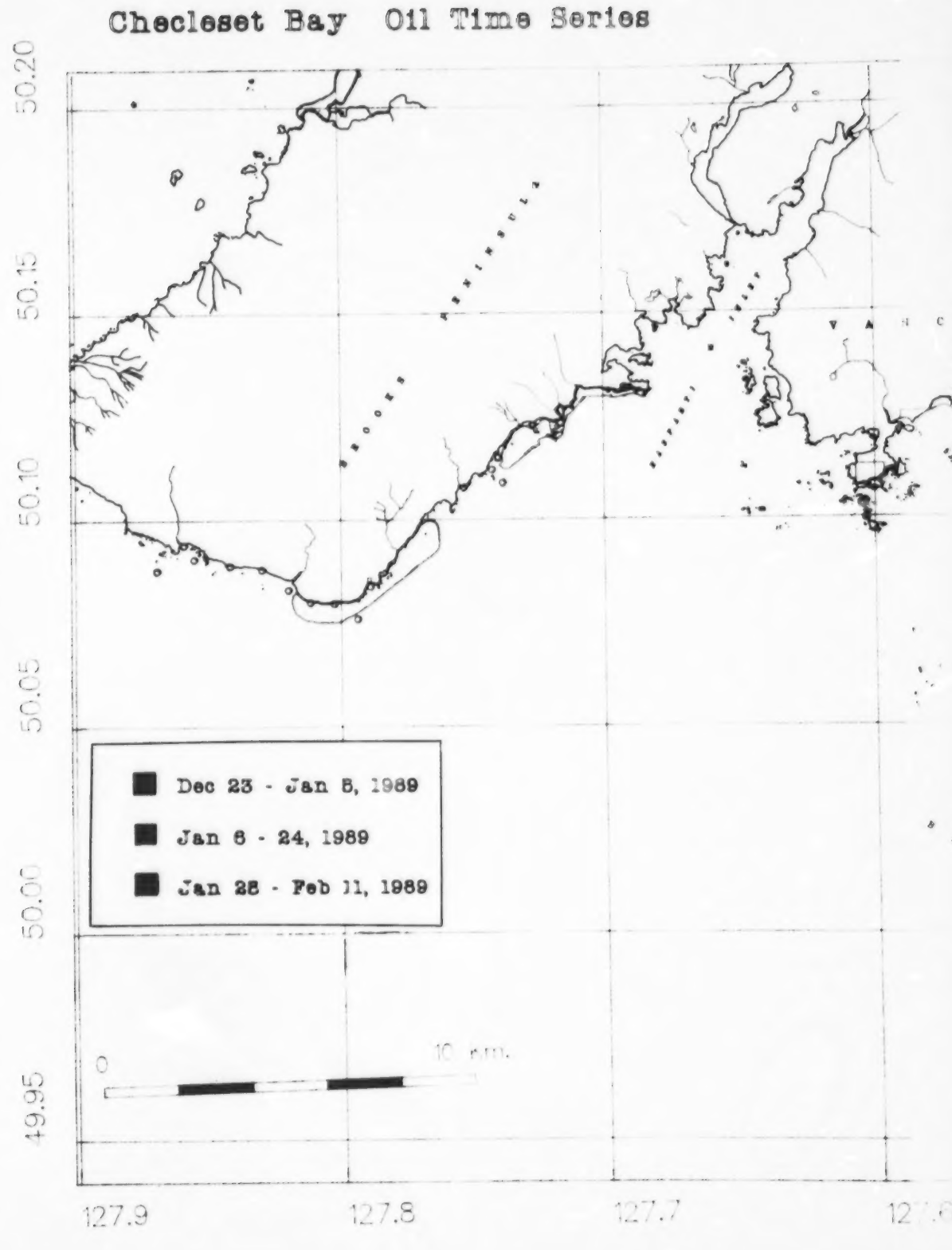


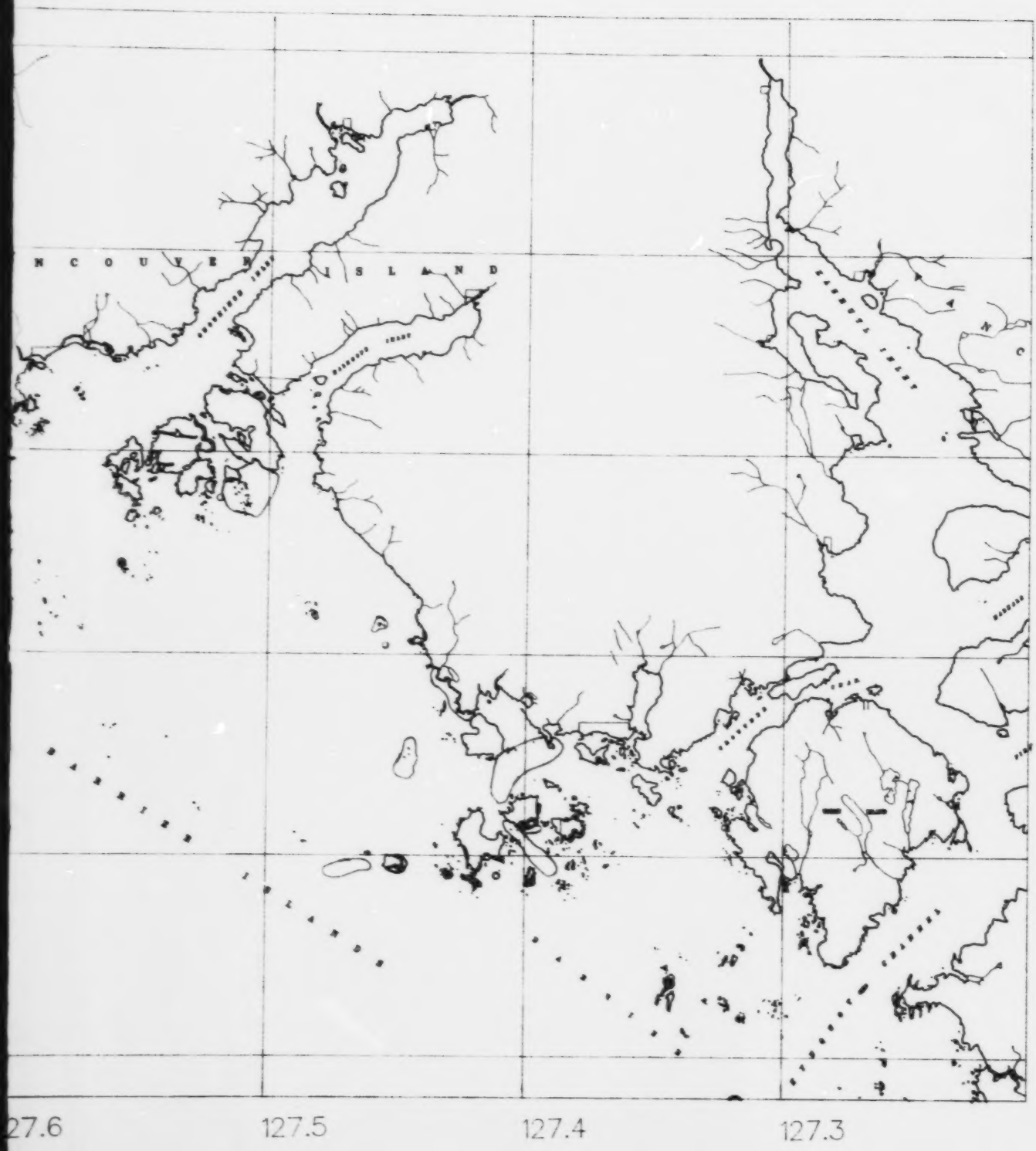

NOOTKA
ISLAND
NOOTKA SOUND
Escalante
Split Cape
Barcester Bay
PENIN
Hornais Cove
Estevan Pt

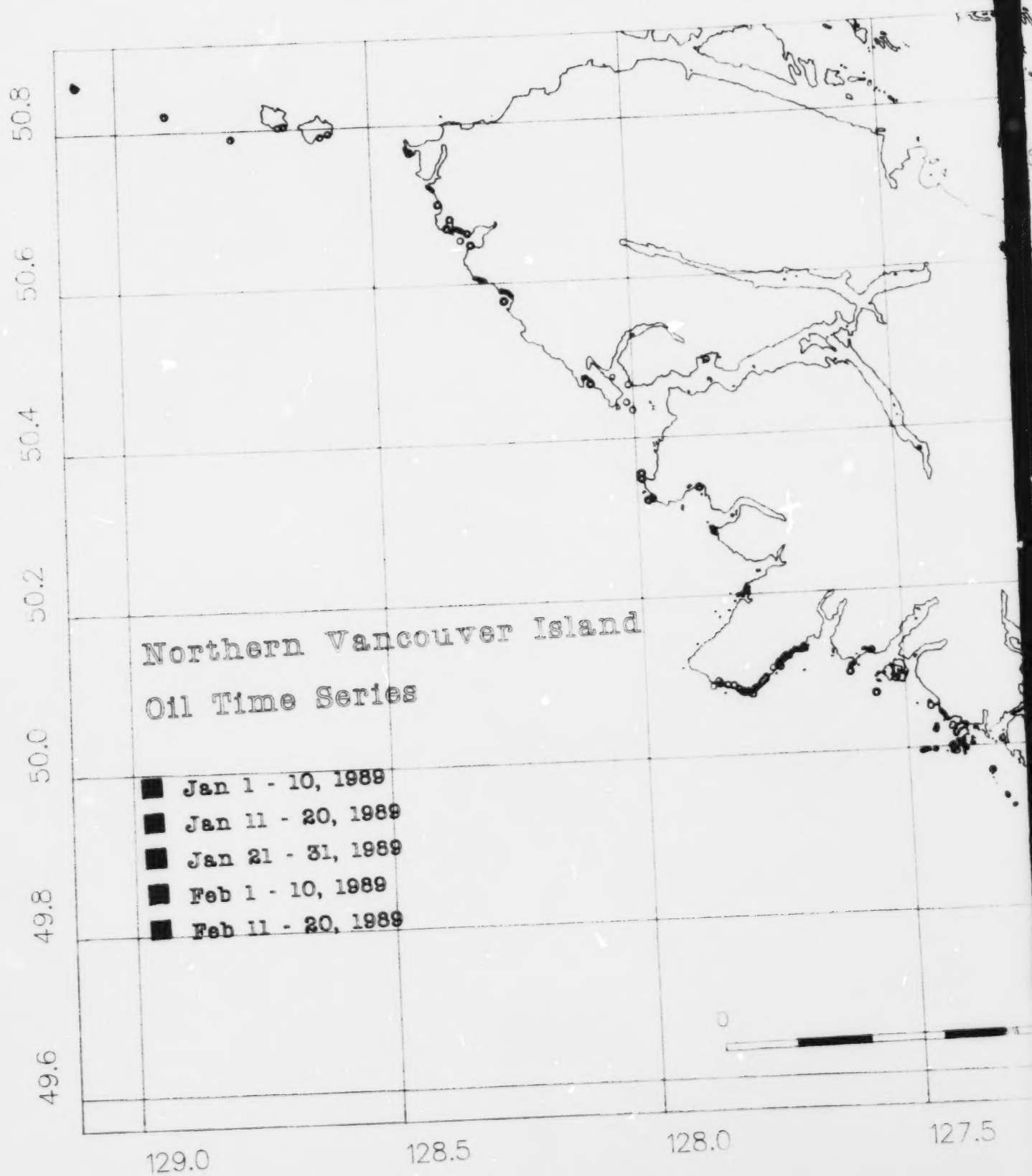
126.6

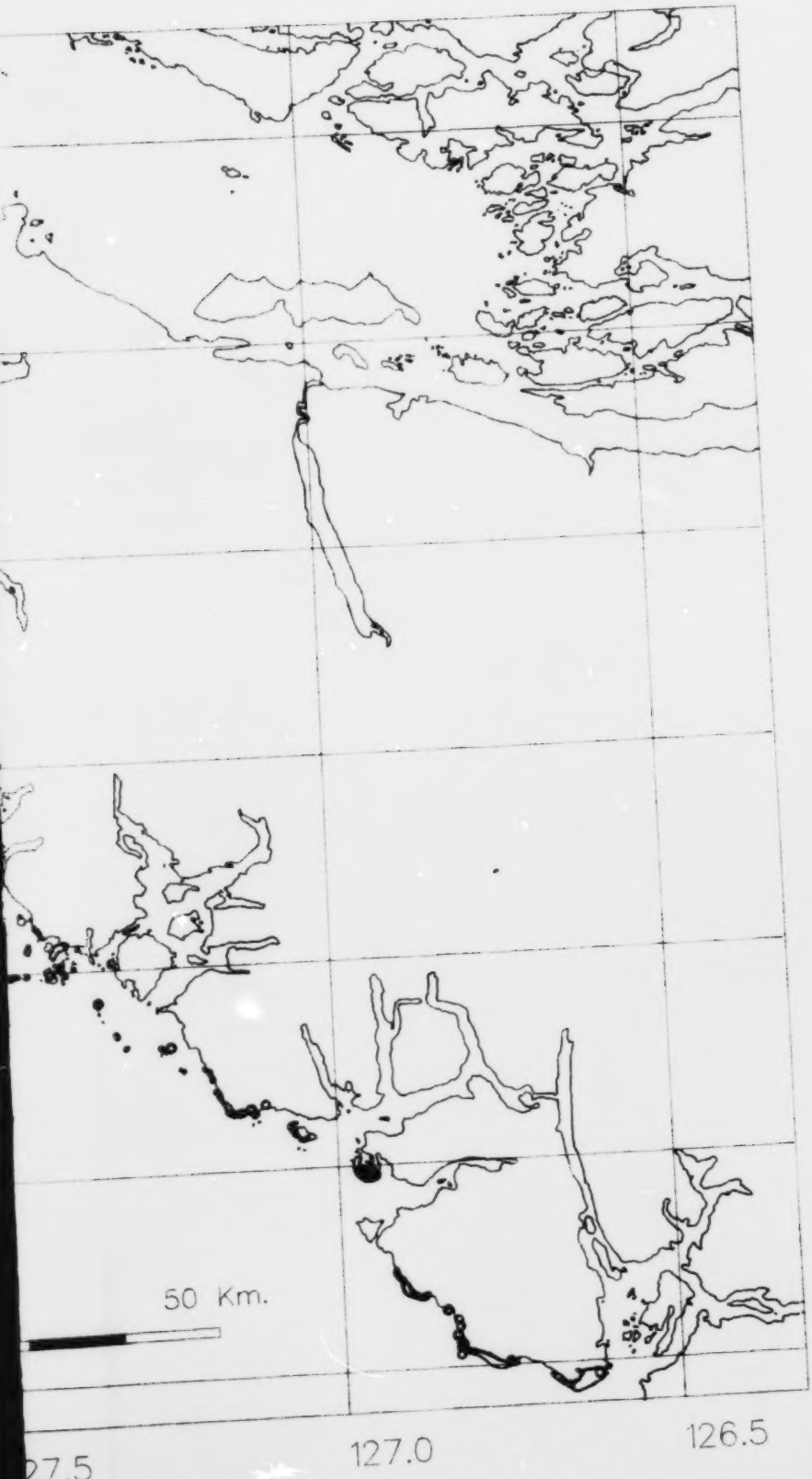

49.75
49.50
49.25
49.00
48.75
48.50
Southern Vancouver Island
Oil Time Series
Jan 1 - 10, 1989
Jan 11 - 20, 1989
Jan 21 - 31, 1989
Feb 1 - 10, 1989
Feb 11 - 20, 1989
0
127.0
126.5
126.0


50 km.
125.5
125.0
124.5

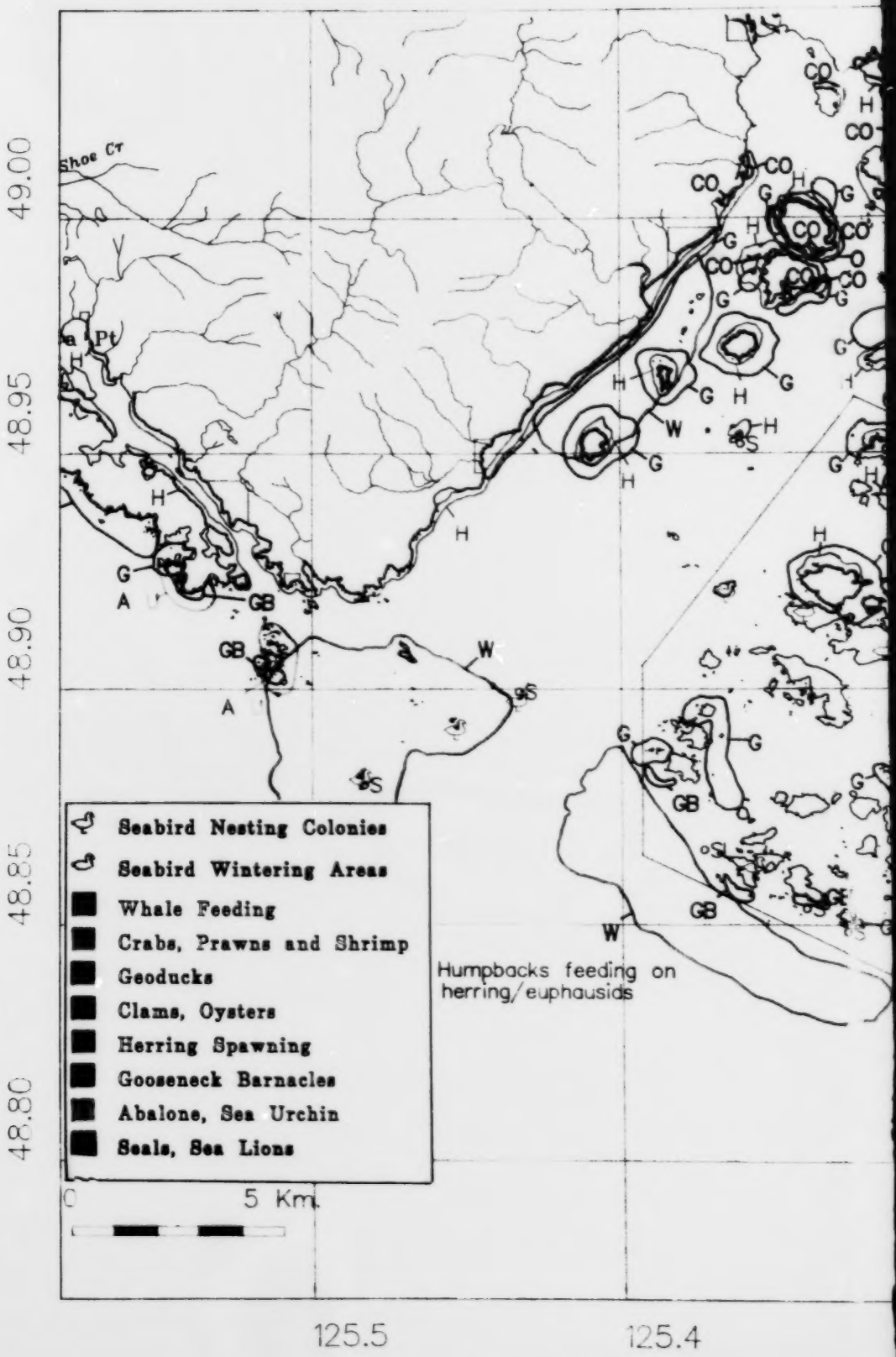

Checleset Bay Oil Time Series
50.20
50.15
50.10
50.05
50.00
49.95
127.9
127.8
127.7
Dec 23 - Jan 5, 1989
Jan 6 - 24, 1989
Jan 25 - Feb 11, 1989
0
10 km.

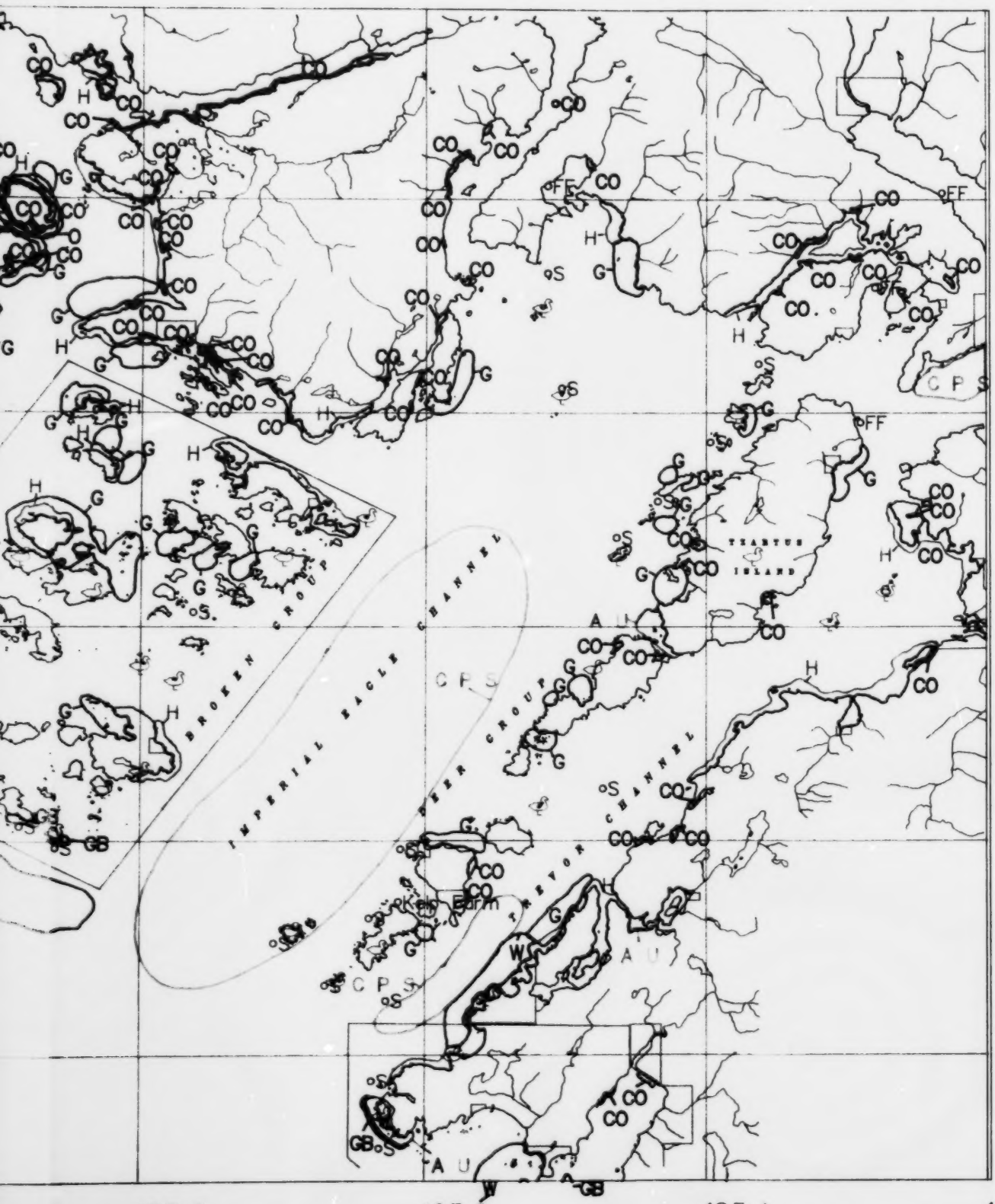

127.6
127.5
127.4
127.3


Northern Vancouver Island
Oil Time Series
Jan 1 - 10, 1989
Jan 11 - 20, 1989
Jan 21 - 31, 1989
Feb 1 - 10, 1989
Feb 11 - 20, 1989
0
50.8
50.6
50.4
50.2
50.0
49.8
49.6
129.0
128.5
128.0
127.5

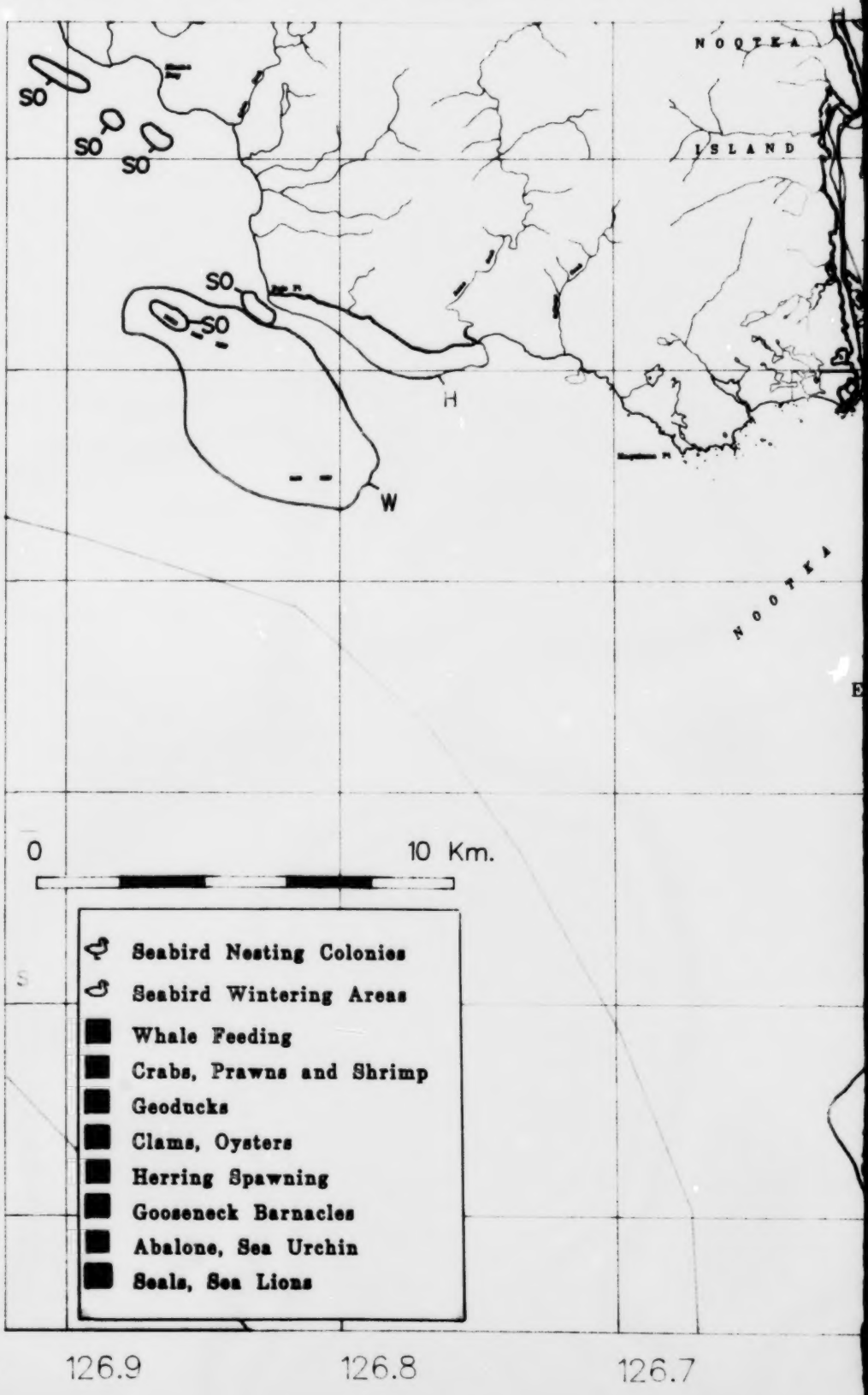

50 Km.
27.5
127.0
126.5

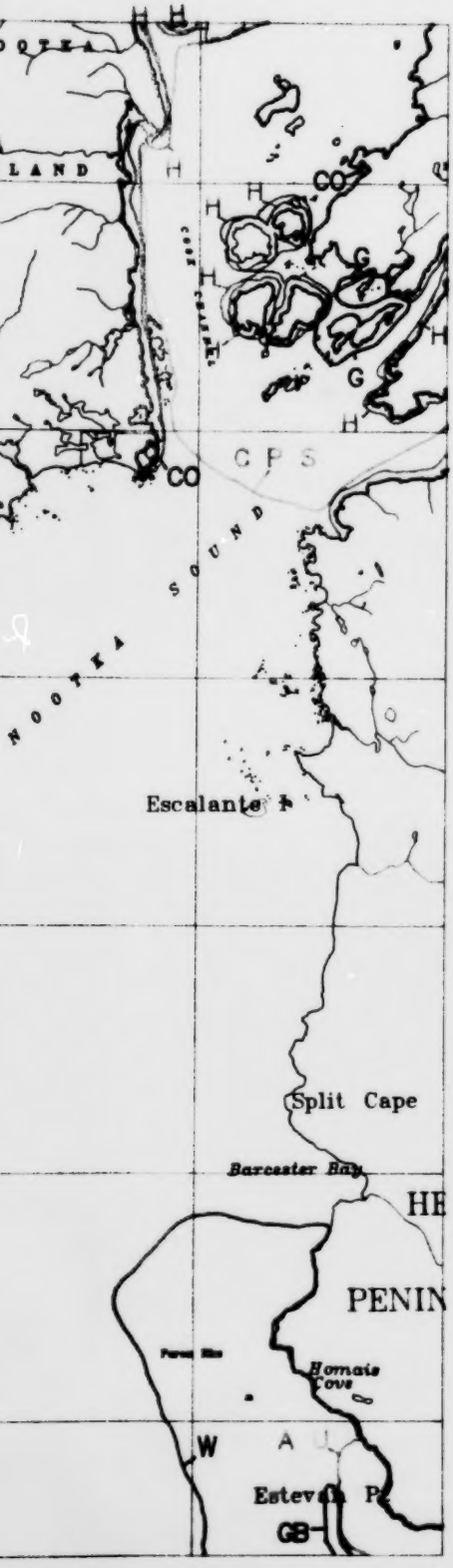
Barkley Sound Marine Resources at Risk




FROZEN GROUP
IMPERIAL EAGLE CHANNEL
PEER GROUP
TRETOR CHANNEL
TRANTOR ISLAND
Keep Farm
125.3
125.2
125.1
125.0

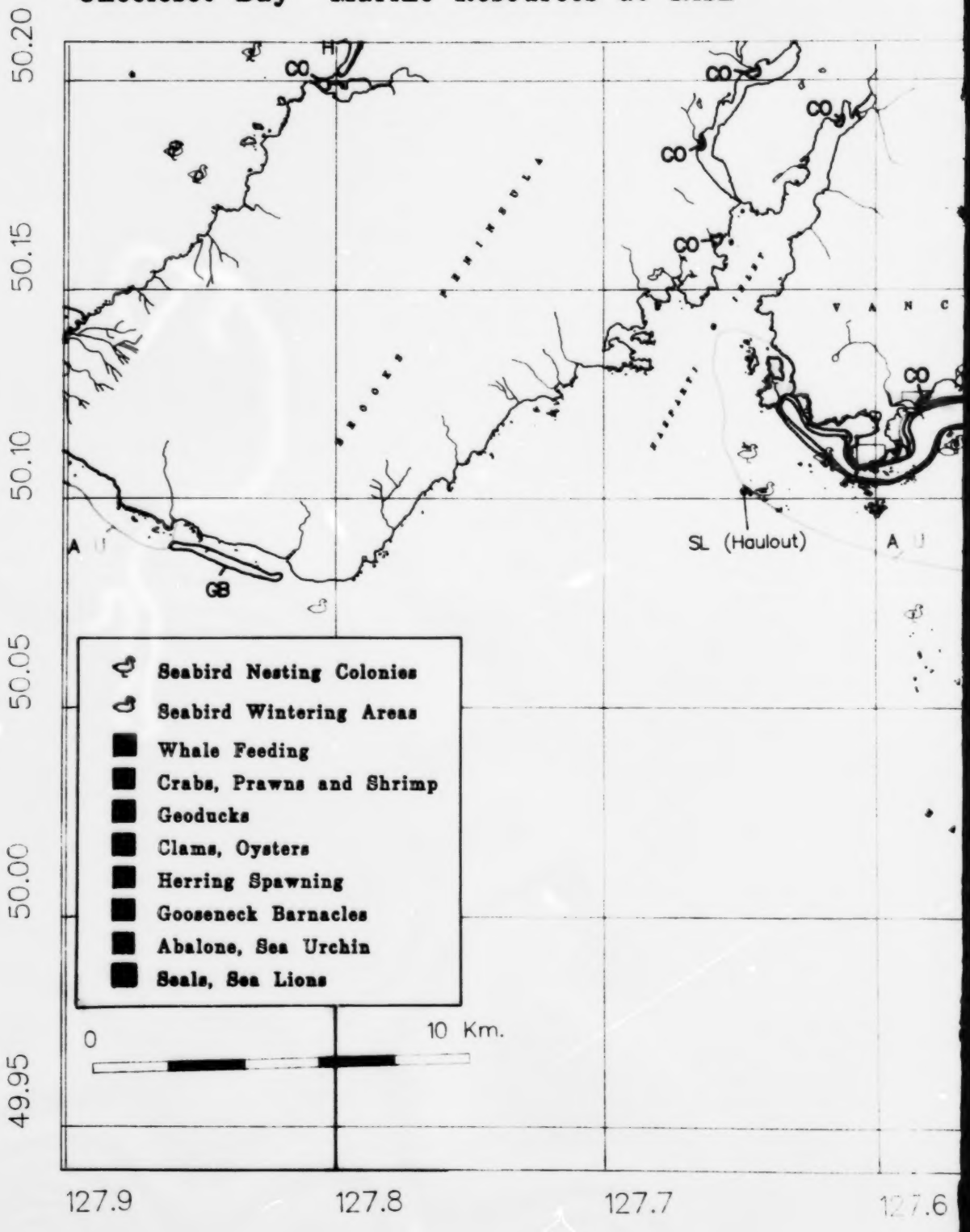
Nootka Sound Marine Resources at Risk

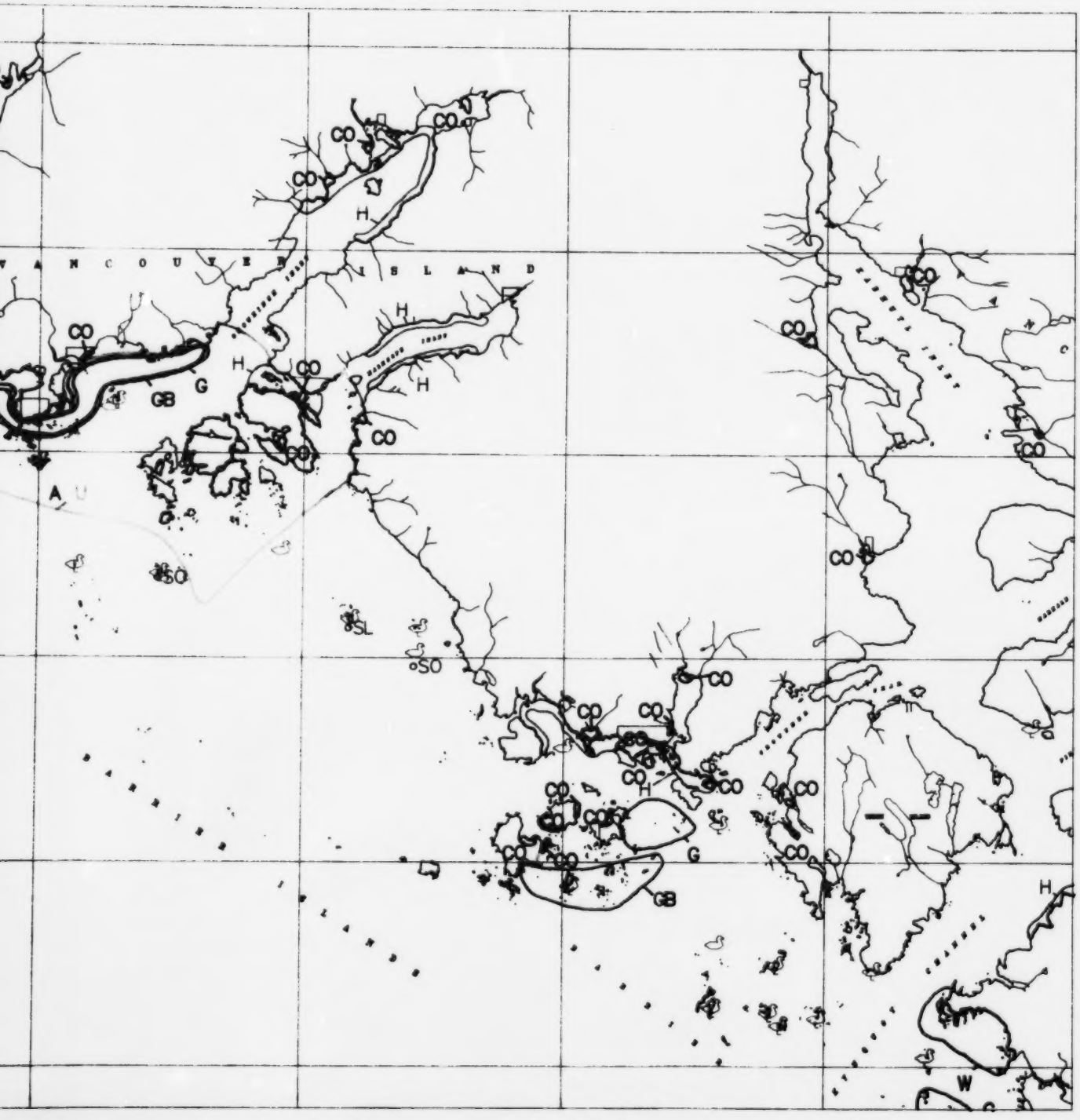



LAND
CPS
SOUND
Escalante
Split Cape
Barcester Bay
PENIN
Homais Cove
W
A
GB

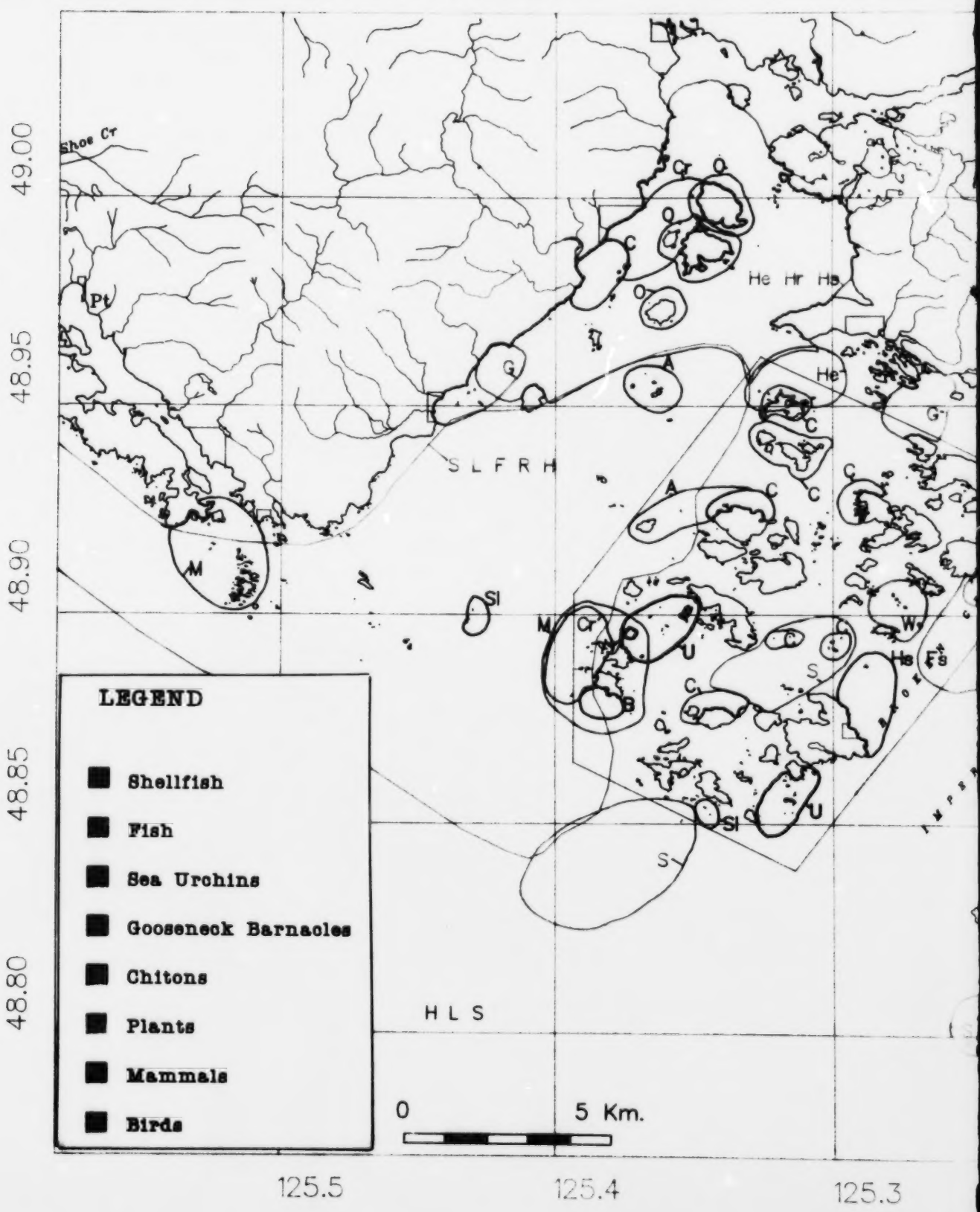
126.6

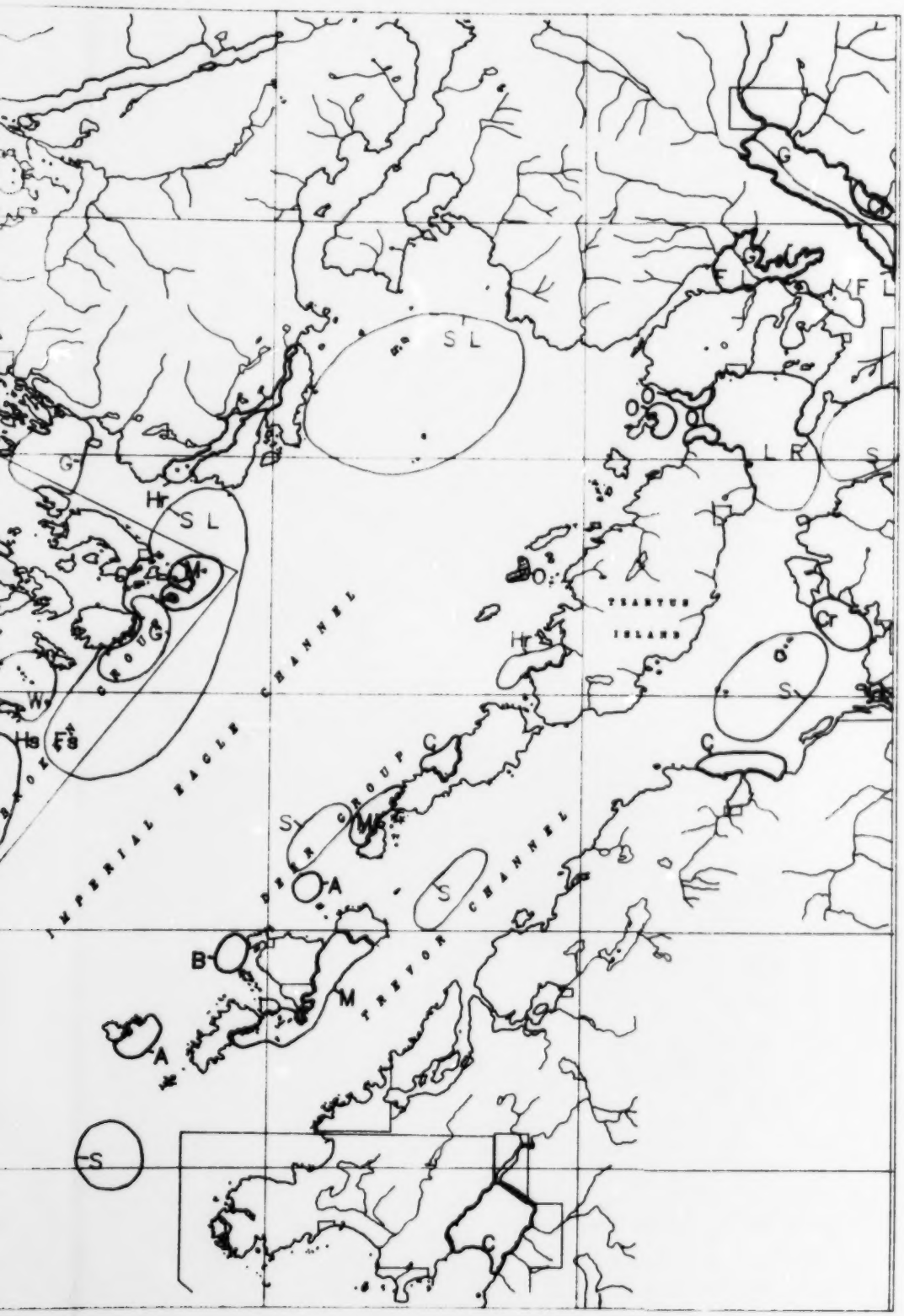
Checleset Bay Marine Resources at Risk




VANCOUVER ISLAND
CO
H
G
GB
A U
SO
SL
W
127.6
127.5
127.4
127.3

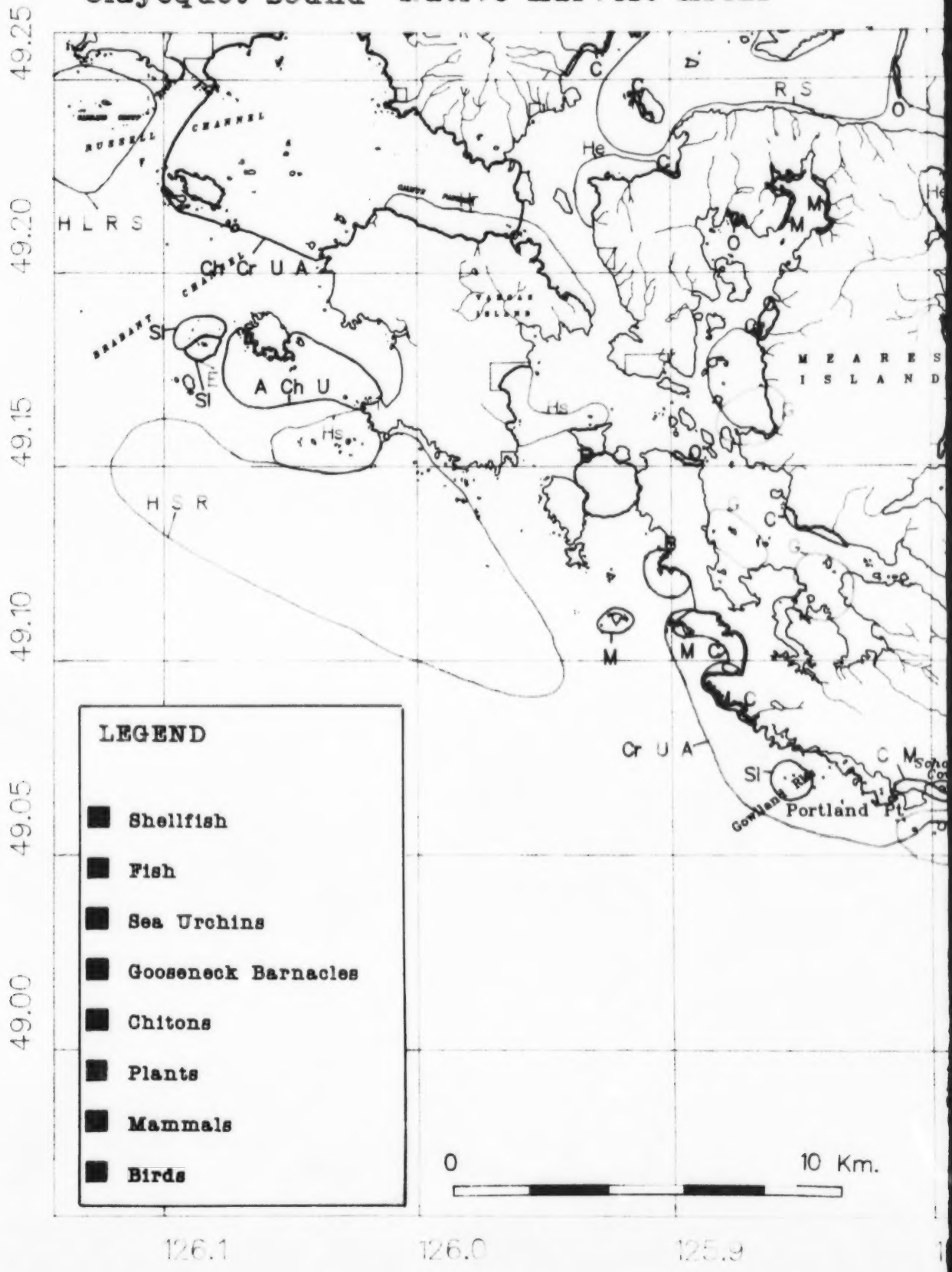
Barkley Sound Native Harvest Areas

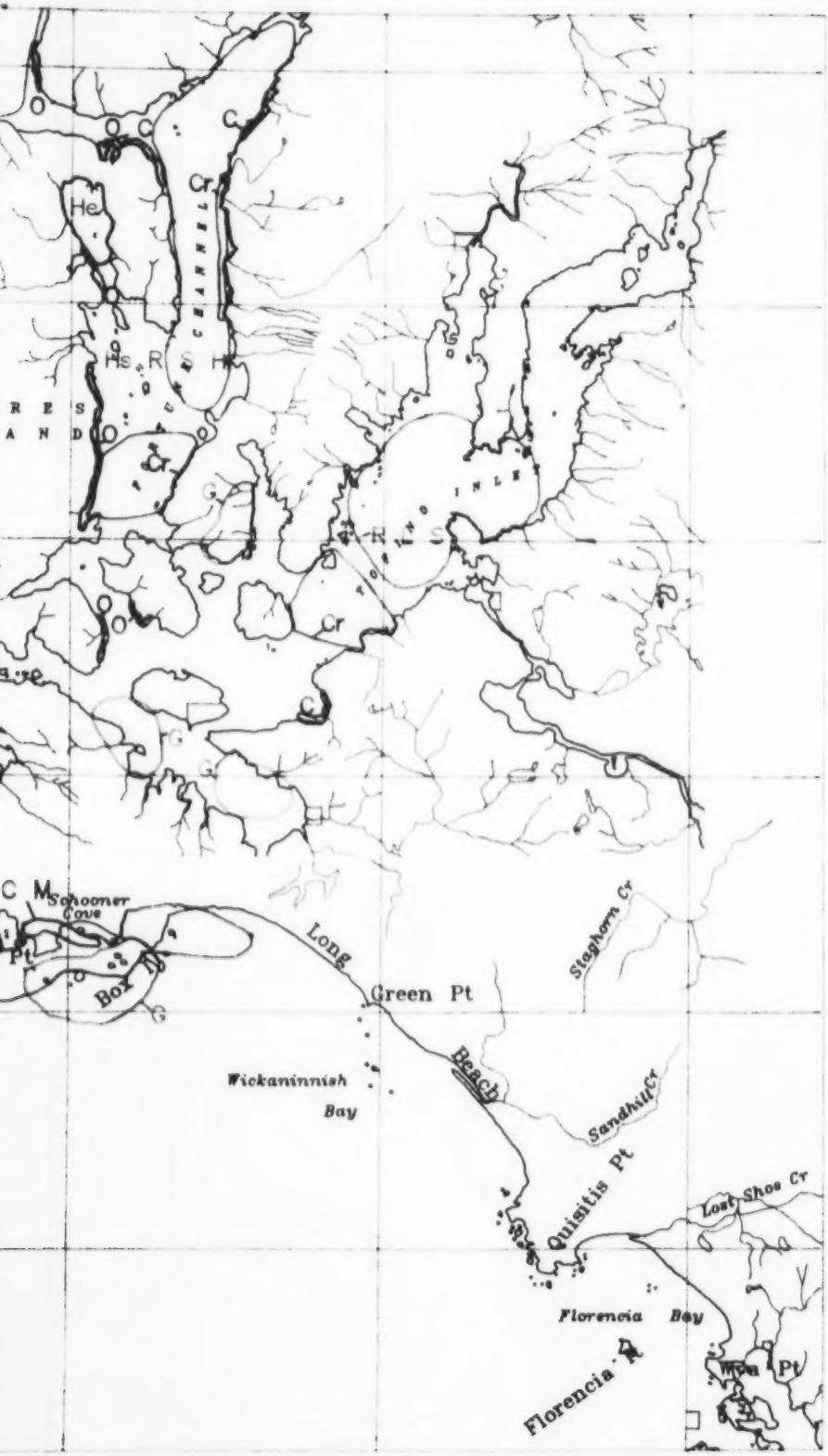




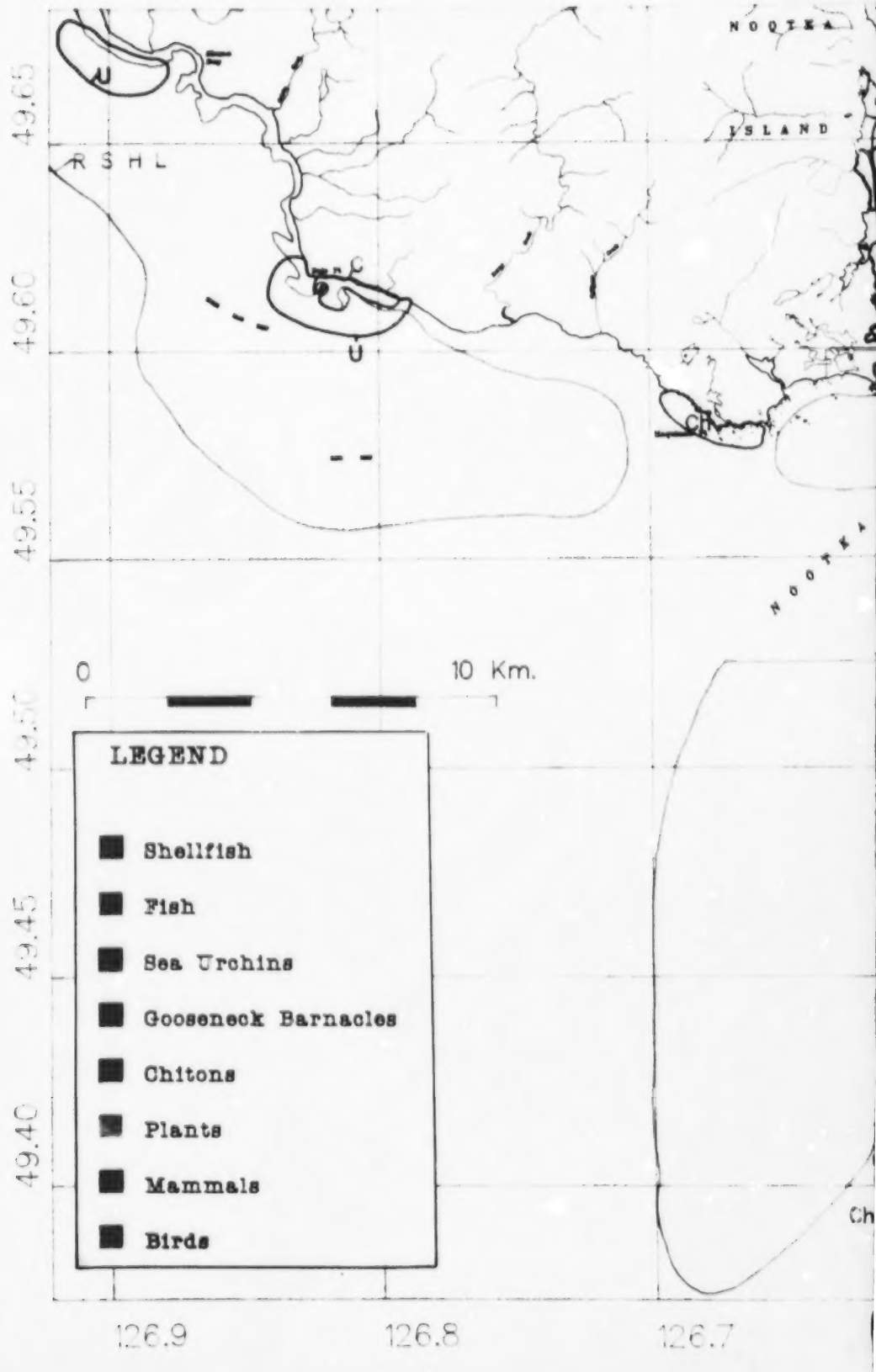
3 125.2 125.1 125.0

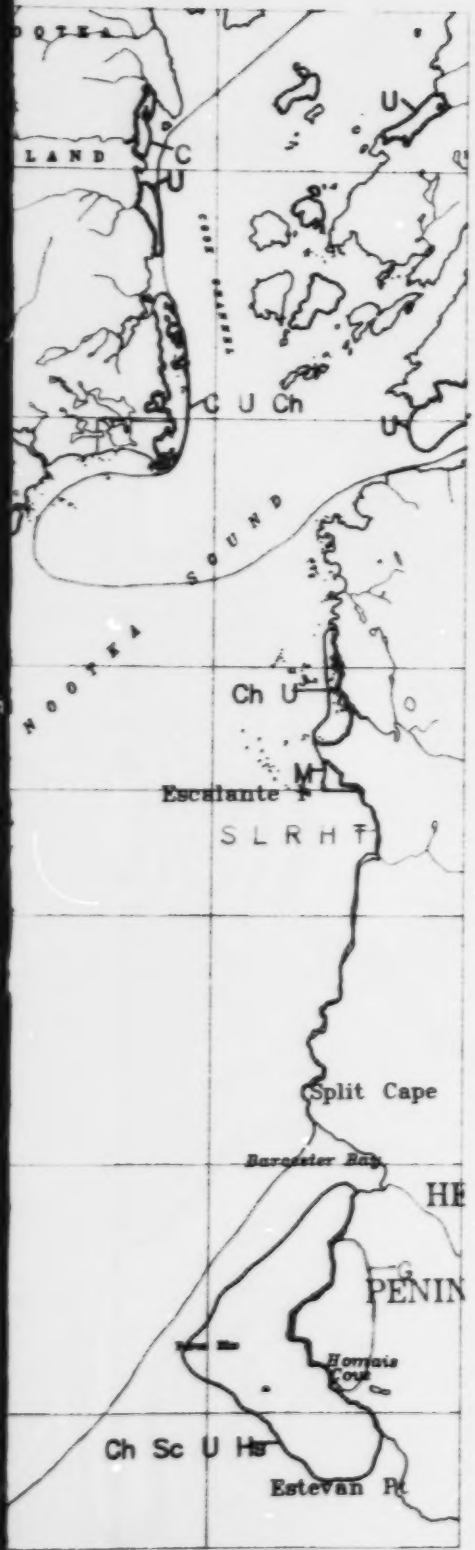
Clayoquot Sound Native Harvest Areas




Schooner Cove
Long
Green Pt
Stephens Cr
Box
Wickaninnish Bay
Beach
Sandhill Cr
Quisitis Pt
Lost Shoe Cr
Florencia Bay
Florencia
Pt
125.8
125.7
125.6

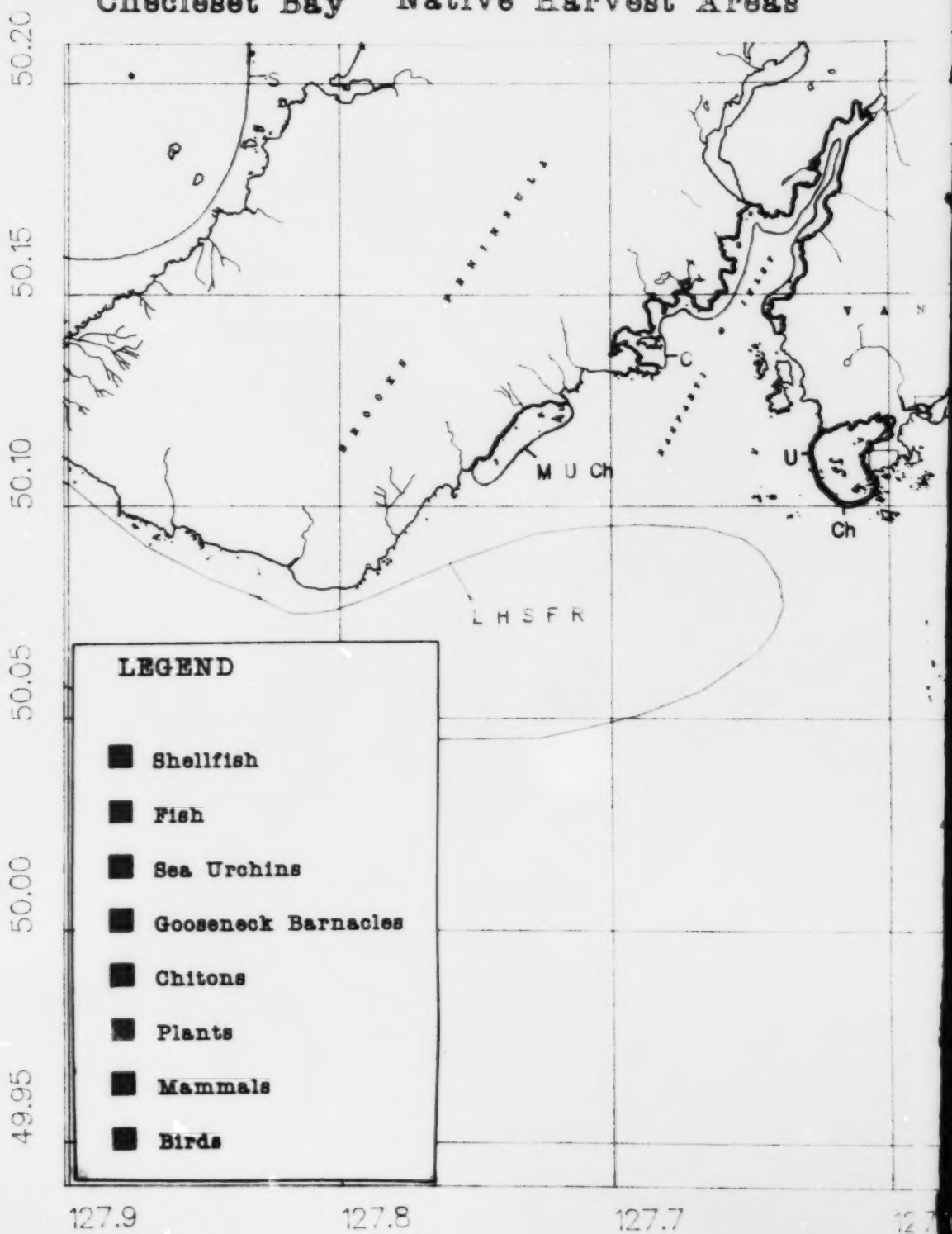
Nootka Sound Native Harvest Areas

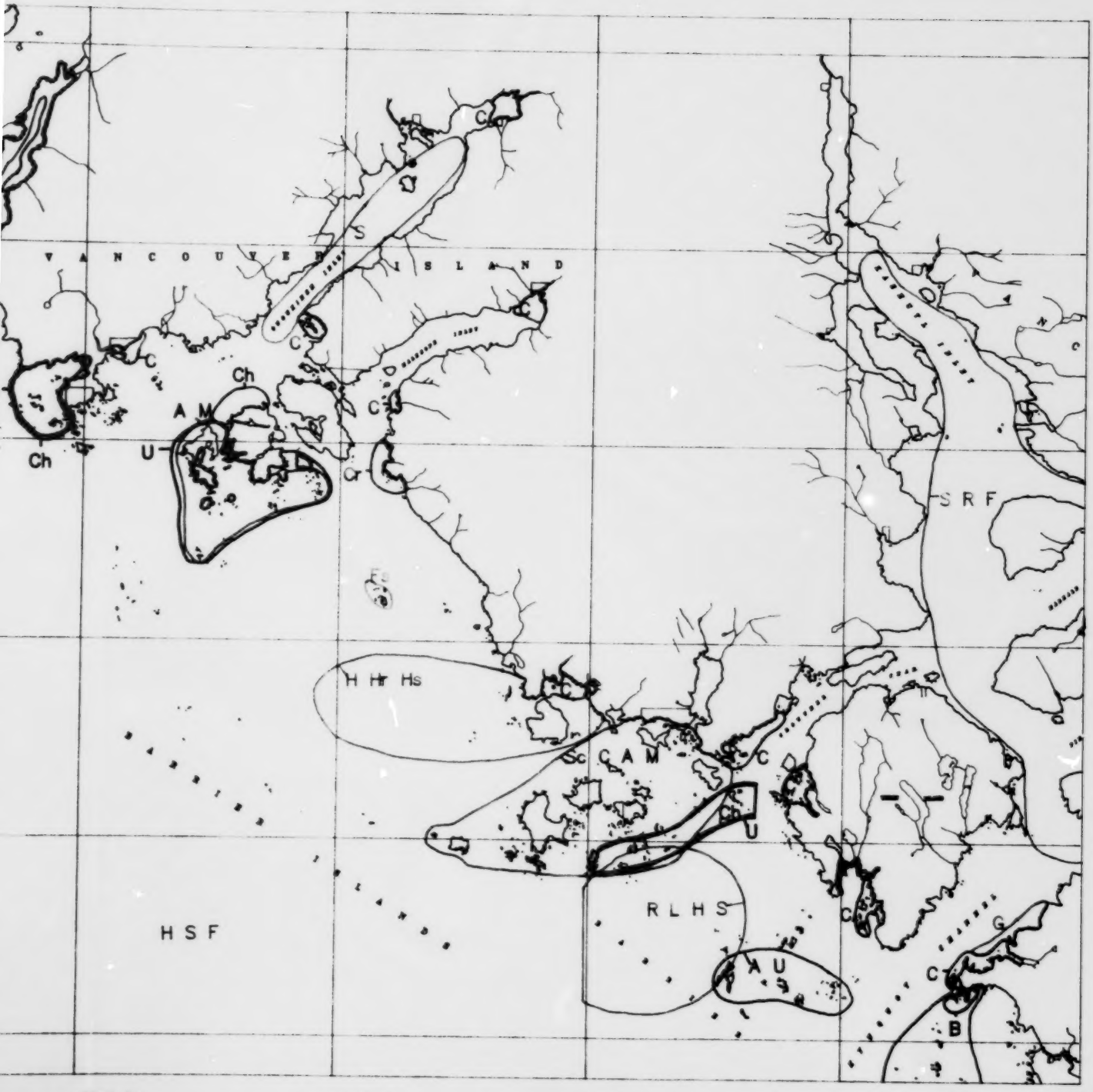



LAND
C
U
U
C U Ch
U
SOUND
Ch U
Escalante Pt
S L R H T
Split Cape
Worcester Bay
HE
PENIN
Hermite Cove
Ch Sc U Hs
Estevan Pt

126.6

Checleset Bay Native Harvest Areas




V A N C O U V E R I S L A N D
S
C
Ch
A M
U
Ch
Cr
S R F
H Hr Hs
C A M
U
R L H S
H S F
A U
G
B
127.6
127.5
127.4
127.3